

The Eugleninae of Malaya

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Summary

AN ACCOUNT is given of 125 species and forms of Eugleninae found in Malaya, of which 11 are described for the first time.

The Eugleninae form a very important part of the micro-flora in standing freshwater in Malaya, particularly where there is a great deal of organic decay going on, or where the water harbours an abundant plant-growth. Indeed, they may be so abundant as to colour the water; for example, the brick red scums so common on Chinese fish-ponds, and on newly flooded rice-fields, are almost entirely due to *Euglena sanguinea* Ehrenberg. However, despite their abundance, the Eugleninae have been very little studied here, and I have been able to find reference to only three species in all the literature on the Malayan freshwater micro-flora. This is because the amount of algological work which has been done in Malaya has been very limited, and most of it has been carried out on preserved material taken to laboratories elsewhere. The Eugleninae, on the other hand, must be studied in the living, and freshly killed state, if sufficiently accurate identification is to be carried out. The present paper deals with 125 species and forms, of which 11 appear to be new. This is certainly not the total number of species to be found in Malaya, and already one or two other forms have turned up, differing from those described in this paper, but which will need further study before they can be adequately identified. Slides of the new species and varieties will be deposited in the Herbarium, Botanic Gardens, Singapore.

The Eugleninae form a class of flagellates which are highly differentiated, but whose origins are obscure. Characteristically they are naked, without a cellulose cell wall as in the Chlamydomonadaceae of the Chlorophyceae. The *periplast*, or bounding membrane of the protoplast may be relatively soft so that the cell may be very metabolic, changing its shape with ease, as in *Euglena*, or it may be rigid, permitting very little change in shape, as in *Phacus*. In most cases the periplast is striated, although the striations may be fine or coarse, and in some cases the membrane may

be ribbed as well. In *Trachelomonas*, *Strombomonas* and *Ascoglena*, the protoplast is enclosed in a firm envelope, or *lorica*, usually of very distinctive shape, and the protoplast can often be seen squirming within the envelope. These encapsulated types parallel the occurrence of *Phacotus* in the Chlamydomonadaceae. One genus, *Colacium*, forms attached dendroid colonies, the cells acquiring flagella and leaving the colony only during reproduction. Two species of *Euglena* also form attached stages, but they can readily leave the colony, even when not dividing.

All the Eugleninae have a large, centrally-placed nucleus, but the most characteristic feature of the class is the vacuolar system. At the anterior end an invagination of the periplast forms a narrow canal, the *cytostome*, which leads inwards to an enlarged vacuolar swelling, the *reservoir*. These are practically always visible, and their presence is indicated by an apical notch, which in some cases may be distinctly one-sided. There may be one or two flagella passing in through the cytostome and terminating at the base of the reservoir. In the case of uniflagellate species the single flagellum is forked at the base, where it enters the reservoir, suggesting that the biflagellate condition is probably primitive, and that the single flagellum has arisen by fusion of two. (Some authors claim that the flagellar ends extend right down to the nucleus, but evidence on this point is both varied and confusing.) In all the Eugleninae the products of assimilation appear as solid, often quite large granules of paramylum, either as rods, discs, rings or other shapes, the shape usually being constant for a particular species. Paramylum is a polysaccharide, allied to starch, but which does not stain with iodine or chlorzinc-iodide, is insoluble in boiling water, but which will dissolve in concentrated sulphuric acid or in potash.

The Eugleninae can be divided quite naturally into the pigmented forms, comprising the family Euglenaceae, which contain chloroplasts and are usually green in colour, and the colourless forms consisting of the two families Astasiaceae and Peranemaceae. *Cyclidiopsis* Korschikow, which is usually separated in the family Cyclidiopsidaceae, is completely devoid of chloroplasts, but possesses a stigma; it shows such close resemblance to species of *Euglena* that perhaps it ought to be included in the Euglenaceae. Some species of *Euglena* have been observed to lose their chloroplasts and live saprophytically under special cultural conditions. The Astasiaceae are without stigma (except *Khawkinia* Jahn & McKibben) and chloroplasts and live saprophytically, but one or two species of *Astasia* come very close to colourless forms of

Euglena. The Peranemaceae are decidedly more specialised, showing a marked tendency towards holozoic nutrition. There is in most cases a special organ, the siphon, which in some cases appears as two short parallel rods next to the cytostome and reservoir. In *Entosiphon* it forms a cone shaped tube running nearly the full length of the cell, and capable of being extruded (fig. 8k). The function of these structures is still obscure, and they have been variously described as pumping organs, or the means of ingestion of solid particles.

For the purpose of identification I have largely depended on the following works: "Das Phytoplankton des Süßwassers" Vol iv 'Euglenophyceen' by Hüber-Pestalozzi 1955, "The genus *Euglena*" by Gojdics 1953, "Materiaux pour un Monographie de *Trachelomonas*, *Strombomonas* et *Euglena*" by Conrad & van Meel 1952, "Etude systematique du genre *Lepocinclis*" by Conrad 1935, "Synopsis der gättung *Phacus*" by Pochmann 1942, and various papers by Déflandre, Skvortzow, Playfair and others. In some genera there has been a tendency for the Malayan specimens to be larger than those elsewhere, whereas in some other genera they have been smaller. Such size variations, unless they are very marked, are not of great significance, especially when we know so little about the nutrition and growth of these organisms. In such cases I have preferred to retain the Malayan specimens under the species name rather than separate them as varieties.

Euglenaceae

Possessing green chloroplasts, ranging from discoid to band-shaped, with or without pyrenoids. The green colour may in some cases be obscured by the production of haematochrome. Colourless forms appear, but are so obviously related to the pigmented forms that there is no difficulty in identification.

Key to Genera

Cell with one flagellum

I. Cell freelifving, solitary.

a. Cell without an envelope.

1. Cell decidely metabolic. Paramylum of various shapes *Euglena*.

2. Cell rigid

(a) Cell more or less round in cross-section, paramylum two lateral rings

Lepocinclis.

(b) Cell more or less flattened *Phacus*.

b. Cell with an envelope

1. Envelope with neck or porus distinctly set off; often sculptured, or bearing spines

Trachelomonas.

2. Envelope with the neck tapering off from the main body; rarely sculptured . . *Strombomonas*.

- II. Cell forming attached dendroid colonies, only leaving them to form swimmers *Colacium*.

Euglena Ehrenberg

Cell usually free swimming, or crawling, fusiform to elongate-cylindrical, often twisted, usually very metabolic. Flagellum one, of varying length. Periplast usually distinctly striate. Vacuolar system a typical cytostome and reservoir. Chloroplasts band-shaped, reticulate or discoid, with or without pyrenoids. Paramylum long rods, discs, and also sheathing pyrenoids in some species. Green colour often masked by haematochrome.

Key to the Malayan species

1. Chloroplasts band-shaped 2.
1. Chloroplasts reticulate (iii) *E. mainxi*.
1. Chloroplasts small (less than 6μ) discoid or ovoid 3.
1. Chloroplasts discoid, larger (over 6μ) 12.
1. Chloroplasts spindle-shaped 14.
2. One chloroplast, long and flattened (i) *E. elongata*.
2. Many chloroplasts arranged spirally, ends nearly touching
(ii) *E. synchlora*.
3. Body circular in cross-section 4.
3. Body flattened 8.
3. Body triangular in cross-section 11.
4. No haematochrome 5.
4. With haematochrome, colouring cell red
(vi) *E. chlorophoenicea*.
5. Paramylum discoid or ovoid 6.
5. Paramylum long rods or rectangular plates 7.
6. Pellicle delicately striated, cells not attached
(iv) *E. proxima*.

6. Pellicle faintly striated, cells attached to crustacea but readily leaving the host (v) *E. cyclopicola*.
7. Cell very long, ending in a sharp point. Flagellum short
(vii) *E. acus*.
8. Paramylum granules small 9.
8. Paramylum in large links 10.
9. Paramylum in short rods, ellipsoids or spheres. Body band-shaped, rounded at both ends (viii) *E. ehrenbergii*.
9. Paramylum oval, hexagonal in outline. Body band-shaped, with posterior end truncate or hollowed
(ix) *E. subehrenbergii*.
10. Pellicle yellowish brown, bearing squarish beaded excrescences along the striae (x) *E. fusca*.
10. Pellicle hyaline without excrescences, but with a long dorsal keel-like fold. Cell twisted throughout its length
(xi) *E. oxyuris* var. *charkowiensis*.
11. Body triangular in cross-section, twisted. Paramylum in long rods or flat plates (xii) *E. tripteris*.
12. No pyrenoids, Chloroplasts oval or round. Paramylum in short rods or rectangles (xiii) *E. refringens*.
12. With paramylum-sheathed pyrenoids 13.
13. No conspicuous sub-pellicular granules even when stained with neutral red. Cell spindle-shaped .. (xiv) *E. caudata*.
13. With conspicuous sub-pellicular granules, staining with neutral red and arranged in spirals between the striae. Cell spindle-shaped, but very metabolic, withdrawing the tail (xv) *E. granulata*.
14. No haematochrome. Chloroplasts spindle-shaped, spirally arranged. Cytoplasm contains rows of granules staining with neutral red, and arranged between the chloroplasts
(xvi) *E. splendens*.
14. Usually containing haematochrome granules, colouring the cell red. Chloroplasts spindle shaped, but not arranged in any marked spirals. No rows of granules staining with neutral red (xvii) *E. sanguinea*.

(i) ***Euglena elongata*** Schewiakoff 1891 (Fig. 1a).

Cell fusiform, tapering to a point at the posterior end, truncate at the anterior end, $65-70\mu$ long $\times$ $6-7\mu$ wide, Flagellum about $\frac{1}{2}$ body length, but rarely seen, the cell progressing by squirming

movements without appreciably changing its length and breadth. Periplast apparently smooth. Cytoplasm containing a few small scattered granules which stain with neutral red. Paramylum not observed. Chloroplast, single, long band-shaped, stretching most of the length of the cell. Pyrenoids none. Eye-spot small, anterior.

Collected from the lake in the Botanic Gardens, Singapore, and from fish-ponds and padi swamps in Malacca.

Recorded also from New Zealand and U.S.A.

The Malayan specimens differ from the descriptions given by Johnson (1944) and Lemmermann (1910) in the smaller eye-spot, and the frequency with which the cell loses its flagellum, but in all other respects they are similar, so that it seems justifiable to place them under this species.

(ii) **Euglena synchlora** Gojdics 1953 (Fig. 1k).

Cell broadly fusiform, tapering gradually to a point at the posterior end, round anteriorly, with the cytostome placed distinctly laterally, 70μ long $\times$ 22μ wide. Flagellum about twice body-length, very active, spiralling slowly even when the cell was stationary. Pellicle finely but distinctly striated in steep spirals. Cytoplasmic granules staining with neutral red, very few. Paramylum granules ovoid, up to 6μ long, abundant. Chloroplasts elongate band-shaped, $12\text{--}15\mu$ long $\times$ 3μ wide, arranged end on end to almost touch, so that they look like continuous bands, five spirals being visible at a time. The chloroplasts are often difficult to distinguish, but show up in specimens freshly killed with osmic acid vapour, and viewed with phase contrast. Pyrenoids none. Eyespot, large, deep crimson. Cysts not seen. The cells were very metabolic, contracting in length at the slightest stimulus.

Collected from the lake in the Botanic Gardens, Singapore, and once from a drain in Malacca.

Reported from U.S.A. by Gojdics.

The characteristic shape and arrangement of the chloroplasts make it certain that the Malayan specimens belong under this species.

(iii) **Euglena mainxi** Déflandre 1928 (*E. reticulata* Mainx 1926) (Fig. 1p).

Cell ovoid to elongate ovoid, tapering gradually to a point at the posterior end, broadly rounded at the anterior end, 45μ long $\times$ $12\text{--}15\mu$ wide. Flagellum about body length, but often withdrawn. Pellicle apparently smooth. Chloroplast reticulate, extending the full length just within the periplast, except at the very ends. The ramifications were often so fine, that the whole chloroplast appeared uniform, but in favourable specimens the reticulations

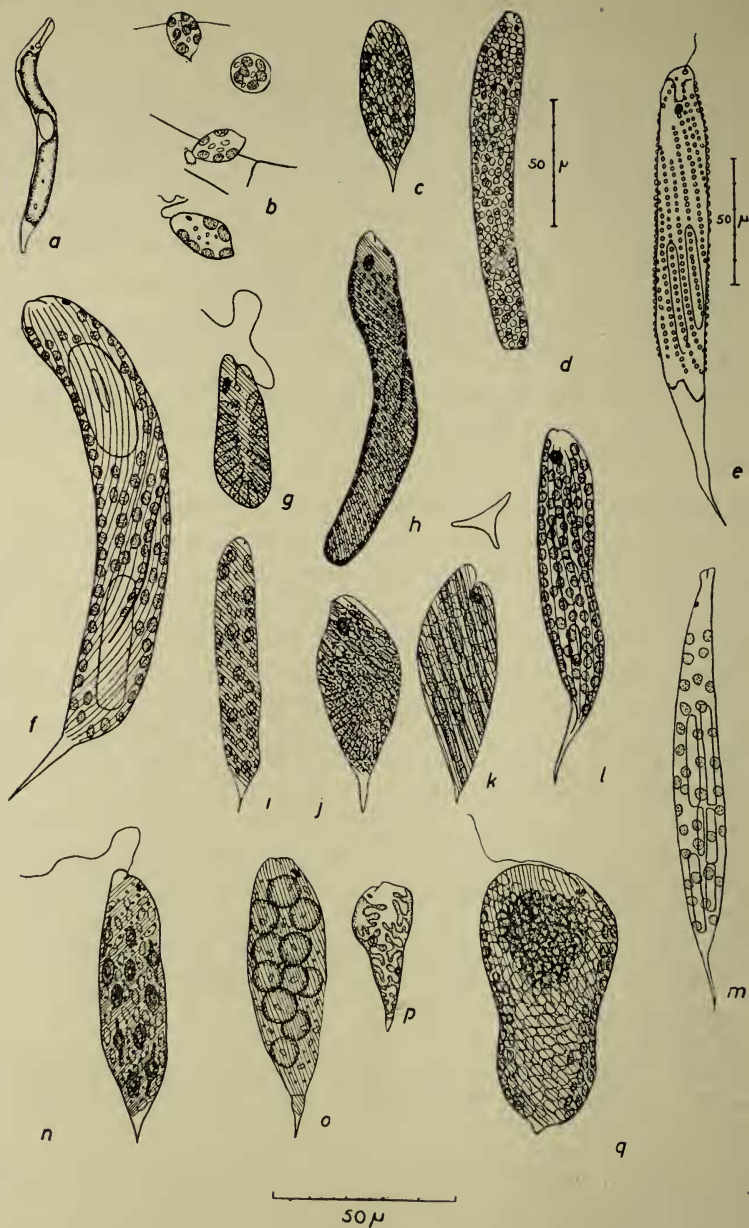


FIGURE 1

Malayan species of *Euglena* Ehrenberg:—

a, *E. elongata* Schewiakoff; b, *E. cyclopicola* Gicklhorn; c, *E. proxima* Dangeard; d, *E. subehrenbergii* Skuja; e, *E. fusca* (Klebs) Lemm.; f, *E. oxyuris* Schmarda var. *charkowiensis* (Swirengo) Chu; g, *E. splendens* Dangeard; h, *E. ehrenbergii* Klebs; i, *E. caudata* Hübner; j, *E. sanguinea* Ehrenberg; k, *E. synchlora* Gojdics; l, *E. tripteris* (Dujardin) Klebs; m, *E. acus* Ehrenberg; n, *E. granulata* (Klebs) Schmitz; o, *E. refringens* Gojdics; p, *E. mainxi* Déflandre; q, *E. chlorophoenicea* Schmarda.

Figures d & e are at a smaller magnification than the rest.

could be followed, while in others they showed up with staining, or with the use of phase contrast. Pyrenoids two, sheathed, often quite plainly visible in the chloroplast. Paramylum, in addition to the sheaths of the pyrenoids, small grains scattered throughout the cytoplasm. Eye-spot crimson, small, spherical. Cysts thin-walled and often forming palmella-like masses.

Collected from the lake in the Botanic Gardens, Singapore, fish-ponds, Malacca and Seremban, and padi swamps and drains, Malacca, common. Originally described from Czechoslovakia.

The reticulate nature of the chloroplasts separates this off from all other species except *E. reticulata* Sjöstedt, marine and without pyrenoids, and *E. limosa* Gard, larger and with many pyrenoids.

(iv) ***Euglena proxima*** Dangeard 1901 (Fig. 1c).

Cell fusiform, tapering to a point posteriorly, rounded at the anterior end, $45\text{--}60\mu$ long $\times 15\text{--}20\mu$ wide. Flagellum about two-thirds body length. Periplast very finely striated. Cytoplasm granular, the granules appearing as spindles arranged spirally when stained with neutral red. Paramylum ovoid granules of varying size up to 6μ in diameter, often so densely crowded as to make other details difficult to distinguish. Chloroplasts parietal, lenticular to oval, 3μ in diameter, numerous. Eyespot bright crimson, prominent. Cysts spherical, with a dense brownish wall immediately around the cell, paler outside. The cells swim by slowly rotating forward, but are so very metabolic that they easily round up.

Collected from fish-ponds, swamps and drains, Malacca, Port Dickson and Seremban. Cosmopolitan in distribution.

The slightly smaller size of the Malayan specimens is not sufficient reason to separate them off as a variety.

(v) ***Euglena cyclopicola*** Gicklhorn 1925 (Fig. 1b).

Cell ovoid to globose when attached, cylindrical to ovoid in the free-swimming state, $14\text{--}20\mu$ long $\times 10\text{--}12\mu$ wide. Flagellum about body length when the cell is swimming, but not visible in the attached stage. Periplast very faintly striated, often appearing smooth. Cytoplasm, when stained with neutral red, showing scattered small, spherical granules. Paramylum granules small, discoid. Chloroplasts parietal, $8\text{--}10\mu$ lenticular bodies $3\text{--}5\mu$ diameter. This species lives attached to small crustacea by the anterior end, the mode of attachment being a short gelatinous stalk terminating in a disc at the point of attachment. This species has been included under the genus *Colacium* by Bourelly (1947) but it so readily leaves the host, and in the frequent free-swimming state

shows remarkable resemblance to various obscure, small forms of *Euglena* which have been described from time to time.

Collected regularly from a fish-pond in Malacca.

Reported also from Czechoslovakia, Hungary and U.S.A.

(vi) ***Euglena chlorophoenicea*** Schmarda 1846 (Fig. 1q).

Cell cylindrical, tapering at the posterior end to a short point, which may become blunt or even retracted, at the anterior end tapering slightly while swimming, but becoming broadly rounded when stationary, 100μ long $\times$ 20μ wide when swimming, 80μ long $\times$ 40μ wide when static. Flagellum less than half body length. Periplast prominently, spirally striate. Colour of the cells almost brick-red due to large numbers of orange-red haematochrome granules distributed more or less evenly throughout the cytoplasm. Other cells in which the haematochrome had clumped in the centre, appeared dull green in colour, since the colour of the chloroplasts could then show through. Paramylum ovoid bodies up to 5μ long, often densely packed. Chloroplasts parietal, ovoid, $4-5\mu$ long, numerous. Eyespot large, consisting of a prominent clump of crimson granules. Cyst spherical, with laminated gelatinous walls.

Collected by Mr. H. M. Burkill (see acknowledgements) from a small pond in Singapore. Not yet found elsewhere in Malaya.

Reported from Latvia, Germany and U.S.A.

The Malayan specimens were slightly smaller than those reported elsewhere, but this difference is of no significance taxonomically.

(vii) ***Euglena acus*** Ehrenberg 1830 (Fig. 1m).

Cell cylindrical, tapering to a long point at the posterior end, narrowed and truncate at the anterior end, $30-250\mu$ long $\times$ $5-15\mu$ wide. Flagellum not longer than quarter body length. Periplast finely striate longitudinally. Paramylum consisting of rods of varying length, some very long, and up to 10μ in number. Chloroplasts numerous small parietal discs. Pyrenoids none.

Found in practically all collections from fish-ponds, padi swamps and drains, Malacca, Singapore, Port Dickson and Seremban. Cosmopolitan in distribution.

Too well known a species to need much description. It is very variable, and numerous varieties have been described, most of which have been suppressed by Gojdics (1953).

E. acus var. *hyalina* Klebs, differing from the type only in the complete loss of chloroplasts, but still retaining an eye-spot, has occurred from time to time. It may be only a nutritional form.

(viii) **Euglena subehrenbergii** Skuja 1948 (Fig. 1d).

Cells elongate, compressed, very truncate or slightly hollowed at the posterior end, rounded at the anterior end, 170μ long $\times$ 20μ wide. Periplast firm with spiral, punctate striae which were not always easy to see. Paramylum oval or hexagonal granules (not spherical), slightly larger than the chloroplasts. Chloroplasts parietal, discoid, $3-5\mu$ in diameter, numerous. Pyrenoids none. No flagellum was seen, the cell progressing by squirming movements without much change in length or breadth, metaboly being slight.

Collected from fish-ponds and padi swamps (several times), Malacca.

Reported originally from Sweden.

This species differs from *E. ehrenbergii* Klebs in the hexagonal paramylum granules (not spherical as in that species) and the markedly truncate posterior end. The Malayan specimens differ from Skuja's original description in that the striae are not nearly so prominent, but this hardly seems an important difference, since varying nutritional changes may affect the nature of the periplast.

(ix) **Euglena ehrenbergii** Klebs 1883 (Fig. 1h).

Cell flat to cylindrical, with sides nearly parallel, but sometimes twisted, rounded at both ends, but slightly narrower at the anterior end, $110-200\mu$ long $\times$ $15-20\mu$ wide. Flagellum not seen, the cell being very metabolic, contracting and expanding, and twisting, sometimes to as short as half normal length. Cytoplasm very finely granular. Periplast plainly, but delicately striate in spirals. Paramylum spherical granules with depressed centres, about half the size of the chloroplasts. Chloroplasts parietal, discoid, $3-4\mu$ in diameter, numerous. Pyrenoids none.

Collected from the lake in the Botanic Gardens, Singapore, and from padi swamps and rain pools, Malacca, but not together with the preceding species.

Reported also from Germany, Russia, Hungary, U.S.A. and China.

Distinguished from the preceding species by the marked metaboly, the shape of the paramylum granules and the rounded posterior end. Gojdics (1953) states that this species is larger, but from the range of sizes quoted by her this is not particularly evident.

(x) **Euglena fusca** (Klebs) Lemmermann 1910 (Fig. 1e).

Cells long, flat, with sides nearly parallel, but often twisted, ending posteriorly in a sharp tail-piece, rounded at the anterior end,

150–230 μ long $\times$ 15–20 μ wide. Periplast brownish in colour, with spiral rows of hemispherical to squarish excrescences. Rows often incomplete or even absent. Flagellum always very short. Paramylum two large links, usually one anterior and one posterior to the nucleus, and occasionally several smaller ones as well. Chloroplasts parietal, ovoid, 3 μ long, numerous. Eyespot dark red, prominent. Cysts, with the contents rounded up as in other species were not seen, but frequently extended specimens were found surrounded by a tightly-fitting, firm hyaline wall, from which the cell later burst. The cells swam by a slow, forward, rotating movement, and were weakly metabolic, able to contract to about $\frac{2}{3}$ normal length.

Collected from the lake in the Botanic Gardens, Singapore, and from fish-ponds, padi swamps, drains and pools in Malacca and elsewhere. The species is probably cosmopolitan in distribution.

This species is so closely allied to *E. spirogyra* Ehrenberg that it is not easy to separate them. Because of the brown colour, the much greater size, and the fact that the chloroplasts seem to touch, I have placed the Malayan specimens under *E. fusca*.

The variation in the size and shape of the excrescences, as described by Lefèvre (1934) and Gojdics (1953) I have been unable to demonstrate except in a few specimens only, even using detached strings of the excrescences under phase contrast. Chu (1946) claims to have demonstrated the identity of the two species in culture, but he makes no mention of the nature of the excrescences. Further work with pure cultures ought to clarify the matter.

(xi) ***Euglena oxyuris*** Schmarda var ***charkowiensis*** (Swirenko) Chu 1946 (Fig. 1f).

Cell elongated, somewhat flattened, with a dorsal keel-like fold producing a shallow groove, frequently spirally twisted, terminating in a prominent colourless tail-piece at the posterior end, rounded at the posterior end, 150–160 μ long $\times$ 20–22 μ wide. Flagellum about half body length. Periplast steeply, spirally, striate from right to left. Paramylum two large links, one anterior and one posterior to the nucleus. Chloroplasts parietal, discoid, 3 μ in diameter, numerous. Pyrenoids none. Eye-spot red, about 3 μ in diameter. Cyst not observed.

Collected from padi swamps and fish-ponds, Malacca.

Reported from Russia, China and India.

The Malayan specimens all belong to this variety, which differs from the type species in possessing a keel-like fold along the dorsal surface.

(xii) **Euglena tripteris** (Dujardin) Klebs 1883 (Fig. 1L).

Cell elongate, commonly twisted throughout its length, ending in a long tail-piece at the posterior end, rounded at the anterior end, distinctly triangular in cross-section, with the sides of the triangle incurved, 100μ long $\times$ 15μ wide. Flagellum about half body length. Periplast clearly striated, the striations following the twists of the cell body. Cytoplasm containing scattered, small granules, which stain with neutral red. Paramylum two rods, one anterior, one posterior to the nucleus. Chloroplasts parietal, small, discoid, numerous. Pyrenoids none. Eye-spot red, prominent. Swims rather rapidly in a rotating manner, but can bend slightly laterally, and can twist to varying degrees about its longitudinal axis.

Collected from fish-ponds, padi swamps in a number of localities in Malaya. Cosmopolitan in distribution.

(xiii) **Euglena refringens** Gojdics 1953 (Fig. 1o).

Cell cylindrical or slightly flattened, often curved or even sigmoid at times, pointed at the posterior end, rounded at the anterior end, 70μ long $\times$ 20μ wide. Flagellum about a third body length. Periplast faintly striated, with the striae running in a steep spiral. Cytoplasm containing a very few granules which stain with neutral red. Paramylum granules very small rods, which when numerous give the cell a distinctly refractive look, and may even make it appear bumpy. Chloroplasts large, lenticular to ovoid, $7-10\mu$ in diameter, 2μ thick, 10-15 in number, strictly speaking parietal, but often becoming displaced with the movements of the cell. Pyrenoids none. Eye-spot light crimson in colour. The cell is very metabolic in movement.

Collected from a padi swamp in Malacca.

Reported from U.S.A.

Despite the fact that the Malayan specimens are larger in every way than those described by Gojdics, the thick chloroplasts, and the highly refractive paramylum granules makes it clear that they belong here.

(xiv) **Euglena caudata** Hübner 1886 (Fig. 1i).

Cell elongate fusiform, tapering strongly to the posterior end, rounded anteriorly, 80μ long $\times$ 10μ wide. Periplast spirally striated, with very fine distinct lines. In addition to the sheaths on the pyrenoids there are numerous small oval or rod-shaped granules scattered throughout the cytoplasm. Flagellum body length. Chloroplasts 15-30 in number, parietal, discoid, with lobed margins and each bearing a doubly-sheathed pyrenoid. Eye-spot

generally very prominent, crimson. The cell is very metabolic, changing shape frequently.

Collected from fish-ponds and padi swamps, Malacca.

Reported from Germany, Russia and China.

Despite the relatively longer shape of the Malayan specimens, the lobed chloroplasts, each with a doubly-sheathed pyrenoid, and the small rod-shaped paramylum granules, make it seem better to place them under this species. In any case, in a markedly metabolic species, shape assumes a relatively lesser importance.

(xv) ***Euglena granulata*** (Klebs) Schmitz 1854 (Fig. 1n).

Cell fusiform, tapering to a point posteriorly, rounded at the anterior end, 80μ long $\times$ 20μ wide. Flagellum about body length. Periplast very distinctly striate. In the cytoplasm, just below the periplast are prominent spherical granules, which readily stain with neutral red; these are arranged in spirals, each two spirals enclosing 3–6 spiral striae of the periplast. Chloroplasts parietal, flat, elliptic 11–15 in number, each bearing a doubly sheathed pyrenoid. In addition there are small ovoid granules of paramylum, about $4.5 \times 3\mu$ scattered in the cytoplasm. Eye-spot small, yellowish-red in colour. Cyst not observed. The cell was very metabolic, the posterior point often being withdrawn.

Collected from a small pond in Singapore (by Mr. H. M. Burkill), where it was abundant, and more rarely in a drain in Malacca.

Reported from Europe and U.S.A.

The prominent sub-pellicular granules make it certain that the Malayan specimens belong here.

(xvi) ***Euglena splendens*** Dangeard 1901 (Fig. 1g).

Cell broadly fusiform, tapering posteriorly, but more frequently rounded owing to the extreme metaboly of the cell, anterior end rounded, $45\text{--}60\mu$ long $\times$ 15μ wide. Flagellum about body length. Periplast showing prominent spiral striae. Cytoplasm containing spiral rows of granules, evident when stained with neutral red, appearing spindle-shaped at the edges and in front views, lying between the rows of chloroplasts; two rows of granules enclose 4–5 striae. Chloroplasts numerous, spindle-shaped, arranged in spiral rows, but appearing radial in optical section. Pyrenoids three to six, lying within the chloroplasts, sheathed with paramylum. Paramylum, in addition to the pyrenoid sheaths, flat discs up to 3μ long, scattered and rather scarce. Eye-spot crimson, granular. The cell swims with constant rotation, but is very metabolic, so that the tapered posterior end rounds up at the slightest stimulus, even while swimming.

Collected from the Botanic Gardens, Singapore, and from fish-ponds and padi swamps Malacca. Cosmopolitan in distribution.

The spiral rows of spindle-shaped chloroplasts, the neutral red granules, and the sheathed pyrenoids make it certain that the Malayan specimens should be included under this species. The commonly rounded shape of the posterior end is not of importance, since the cell is very metabolic.

(xvii) **Euglena sanguinea** Ehrenberg 1830 (Fig. 1j).

Cells broadly fusiform, gradually tapering to a point at the posterior end, rounded anteriorly, $60-100\mu$ long $\times$ $25-30\mu$ wide. Flagellum about body length, but easily shed. Periplast conspicuously and steeply striate. Colour brick red due to the abundance of haematochrome granules dispersed throughout the cytoplasm; when these granules clump in the centre the colour appears olive green, due to the chloroplasts, and in some specimens collected there was no haematochrome at all (except for the eye-spot). Paramylum spherical or ovoid, up to 8μ in diameter, visible in cells with little or no haematochrome. Chloroplasts numerous long spindles, radially arranged, but sometimes showing a tendency to a spiral arrangement. Pyrenoids not visible in the living cell, but showing up on staining in the centre of some of the chloroplasts. Eye-spot crimson, prominent. Cysts spherical, stalked in a jelly-like layer. The cell is somewhat metabolic, often rounding up.

Collected from fish-ponds, Malacca, Seremban, Singapore, and from padi fields, Malacca. Cosmopolitan in distribution.

This species is responsible for the brick red scums on Chinese carp ponds, and on recently flooded padi fields. Its abundance appears to be an indication of heavy application of organic manures.

Lepocinclis Perty 1852

Cell solitary, free-swimming, spherical, ovoid, fusiform or ellipsoidal, circular in cross-section. Periplast usually spirally, sometimes longitudinally striate. Cell rigid, not metabolic. Flagellum one, usually long (2-3 times body length). Vacuolar system typical for the family, with a cytostome and reservoir. Paramylum usually two large rings, laterally placed to curve just inside the periplast; in a few cases it consists of several discs or spheres, and the genus then approaches the condition in *Phacus*. Chloroplasts parietal, numerous, discoid, but sometimes so close together as to become polygonal. Stigma usually well marked. Lives holophytically, but can live saprophytically.

Key to species

1. Striations running spirally to the right (in the direction of the posterior end) 2.
1. Striations longitudinal 10.
1. Striations running to the left 11.
2. Cell much longer than broad (about three times), fusiform to cylindrical, 23μ long $\times$ 8μ wide
(xiii) *L. acicularis*.
2. Cell relatively much shorter 3.
3. Cell with a very short tail-piece, not much more than a wart-like outgrowth, or none at all 4.
3. Cell with a longer conspicuous tail-piece 7.
4. Cell large, broad, with many disc-shaped and ovoid paramylum granules. 60μ long $\times$ 40μ wide .. (i) *L. texta* var. *mamillata*.
4. Cells much smaller (30μ or less) with two lobed lateral ring shaped paramylum granules 5.
5. Cells with a distinct anterior neck-like outgrowth, sub-globose. 20μ long $\times$ 15.5μ wide, neck 1.5 – 2μ long
(x) *L. ovum* var. *colliferum*.
5. Cell without a distinct neck-like outgrowth 6.
6. Cell elongate ovate, with sides nearly parallel, tail short and blunt. 20 – 24μ long $\times$ 15μ wide (iii) *L. ovum* var. *dimidio-minor*.
6. Cell ovate, wider than the preceding, with a distinct anterior notched beak (not a neck). 20 – 24μ long $\times$ 18μ wide
(iv) *L. ovum* var. *major*.
6. Cell rounder, with no beak, tail short and blunt. 19μ long $\times$ 15μ wide (v) *L. ovum* var. *deflandriana*.
6. Cell larger than preceding, posterior end wider than anterior end. Very short beak at anterior end. 33μ long $\times$ 15μ wide.
(vi) *L. ovum* var. *conica*.
7. Tail-piece well-marked but comparatively short ($1/6$ length) cell broadly ovate. 28 – 30μ long $\times$ 18 – 20μ wide
(ii) *L. ovum* forma *ovum*.
7. Tail-piece long 8.
8. Striations verrucose. Cell oblong ovoid. 35μ long $\times$ 17μ wide
(xiii) *L. ovum* var. *verrucosum*.

8. Striations smooth 9.
9. Cell oblong ellipsoidal with almost parallel sides. Tail long and slender ($\frac{1}{2}$ body length); 42μ long $\times$ 22μ wide
(viii) *L. ovum* var. *gracilicauda*.
9. Cell ellipsoidal, narrowing towards both ends, with characteristic swelling at base of tail. 50μ long $\times$ 23μ wide
(vii) *L. ovum* var. *Butschlii*.
9. Cell broadly fusiform, almost rhombic, with smaller swelling at the base of tail. 45μ long $\times$ 20μ wide
(xi) *L. ovum* var. *angustata*.
10. Striations ribbed; cell fusiform to elongate ellipsoidal; periplast often yellowish 30μ long $\times$ 10μ wide
(xiv) *L. steinii*.
10. Striations not ribbed, fine; cell comparatively longer with a narrow neck at anterior end; periplast hyaline. $33-66\mu$ long $\times$ $10-12\mu$ wide (xv) *L. Marsonni*.
11. Cell large, broadly ovate, rounded at posterior end; paramylum numerous small discs; striations running to the left. 50μ long $\times$ 43μ wide (xvi) *L. salina*.

Lepocinclis texta (Duj.) Lemm. em. Conrad var. **mamillata** (Da Cunha) Conrad (Fig. 2a).

Cell broadly oval, tapering to a very short, blunt, tail at the posterior end, rounded at the anterior end, 60μ long $\times$ 40μ wide. Flagellum body length. Periplast spirally striate, the striae running to the right. Paramylum one large central disc, and numerous, scattered, small ovoid granules. Chloroplasts numerous, discoid, parietal. Stigma large, crimson.

Collected from padi swamps, Malacca.

Reported from Brazil.

This variety differs from the type species in that it tapers to a very short blunt tail.

(ii) **Lepocinclis ovum** (Ehrenberg) Lemm. f. **ovum** (Figs. 2c, d).

Cells broadly ovate, rounded at both ends, with a short blunt tail at the posterior end, $28-30\mu$ long $\times$ $18-20\mu$ wide, tail 5μ long. Flagellum about body length. Periplast spirally striate to the right, the density of the striations being variable. Paramylum two large rings, one on either side of the cell. Chloroplasts parietal, discoid, numerous.

Collected from fish-ponds, swamps and ditches in various localities in Malaya, common. Distribution cosmopolitan.

(iii) **L. ovum** var. **dimidio-minor** Défl. (Figs. 2e, f, v).

Differing from the type in the smaller size, elongate ovate shape, with very steep spiral striae. $20-24\mu$ long $\times$ 15μ wide.

Collected from fish-ponds and padi swamps, Malacca. Common. Cosmopolitan in distribution.

(iv) **L. ovum** var. **major** (Hüber-Pestalozzi) Conrad (Fig. 2g, h).

Differing from the type in being narrower, and with a distinct beak like outgrowth at the anterior end, and bearing a very short tail at the posterior end. $20-24\mu$ long $\times$ 18μ wide.

Collected from padi swamps, Malacca, occasional.

Reported from Germany and South Africa.

(v) **L. ovum** var. **deflandriana** Conrad (Fig. 2i, j, k).

Smaller and rounder than the type, broadly rounded at the anterior end, with a very small blunt tail at the posterior end. 19μ long $\times$ 15μ wide.

Collected from fish-ponds, Malacca, occasional.

Reported from France and Indonesia.

(vi) **L. ovum** var. **conica** Allorge and Lefèvre (Fig. 2l).

Wider at the posterior end, bearing a very short tail there, and a very short beak at the anterior end. 33μ long $\times$ 25μ wide.

Collected from fish-ponds, Malacca, occasional.

Reported from France.

(vii) **L. ovum** var. **butschlii** Conrad (Fig. 2m).

Cell ellipsoidal, narrowing towards both ends, bearing a sharp tail at the posterior end, with a characteristic swelling at the base. 50μ long (with tail) $\times$ 23μ wide, tail 15μ long.

Collected from fish-ponds, Malacca, fairly common. Cosmopolitan in distribution.

(viii) **L. ovum** var. **gracilicauda** Défl. (Figs. 2n, o).

Cell oblong ellipsoidal with almost parallel sides, broadly rounded at both ends, and bearing a long slender tail (about $\frac{1}{2}$ body length) at the posterior end. 42μ long $\times$ 22μ wide, tail 12μ long.

Collected from padi swamps, fish-ponds and rain pools, Malacca and Singapore, fairly common.

Reported from France.

(ix) **L. ovum** var. **globula** (Perty) Lemm. (Fig. 2p).

Differing from the type by being almost spherical and with a very long flagellum (about 2-3 times body length) 20μ long $\times$ 19μ wide.

Collected from fish-ponds, Malacca, occasional. Cosmopolitan in distribution.



FIGURE 2

Malayan species of *Lepocinclis* Perty:—

a, *L. texta* (Duj.) Lemm. emend. Conrad var. *mamillata* (Da Cunha) Conrad; b, *L. salina* Fritsch; c-d, *L. ovum* (Ehr.) Lemm.; e-f, *L. ovum* var. *dimidio-minor* Défl.; g-h, *L. ovum* var. *major* (Hüber-Pest.) Conrad; i-k, *L. ovum* var. *deflandriana* Conrad; l, *L. ovum* var. *conica* Allorge & Lefèvre; m, *L. ovum* var. *butschlii* Conrad; n-o, *L. ovum* var. *gracilicauda* Défl.; p, *L. ovum* var. *globula* (Perty) Lemm.; q, *L. ovum* var. *colliferum* Prowse; r, *L. ovum* var. *angustata* (Défl.) Conrad; s, *L. ovum* var. *verrucosum* Prowse; t, *L. acicularis* Francé; u, *L. steinii* Lemm.; v, *L. ovum* var. *dimidio-minor* Défl.; w-x, *L. marsonni* Lemm.; y-z, *Colacium vesiculosum* Ehr.

(x) **Lepocinclis ovum** var. **colliferum** Prowse var. nov. (Fig. 2q).

Differing from *L. ovum* var. *punctato-striato* Lemm., which also has an anterior neck-like outgrowth, by its smaller size, and by the striae not being punctate.

Cell subglobose, broadly rounded at both ends, bearing a conical tail at the posterior end; at the anterior end there is a short cylindrical neck-like outgrowth, from which the flagellum projects. Cell 20μ long $\times$ 15.5μ wide, neck $1.5-2\mu$ long.

A *L. ovo* var. *punctato-striato* Lemm., quod etiam os colliferum producit, haec varietas dimensione minore, striis non punctatis valde recedit.

Cellula subglobosa, utrinque late rotundata, posteriore caudam conoideam, brevissimam gerens, anteriore ore $1.5-2.0\mu$ alto cylindrico flagellifero praedita, flagello cellulae aequilongo, 20μ longa, 15.5μ lata. *Membrana* hyalina striis ad dextram spiraliter tortis praedita. *Paramyla* duo annularia, lateralia. *Stigma* sanguineum, conspicuum, anteriore dispositum. *Chlorophora* parietalia, discoidea, plurima.

Habitat: Malacca in locis paludosis orizicultis (Prowse 182a).

(xi) **L. ovum** var. **angustata** (Défl.) Conrad (Fig. 2r).

Differing from the type in the broad, fusiform, almost rhombic shape, and the slight swelling at the base of the tail spine. 45μ long $\times$ 20μ wide.

Collected from fish-ponds, Malacca, occasional.

Reported from Venezuela.

This variety comes very near to var. *Butschlii* (vide) and possibly should not be separated from it, although no intermediate forms have been seen.

(xii) **Lepocinclis ovum** var. **verrucosum** Prowse var. nov. (Fig. 2s).

Differs from *L. ovum* f. *ovum* by the sharp pointed tailpiece, and the spiral rows of small verrucae. From *L. quadratum* (Kuff.) Conrad it differs by its smaller size, more ovoid shape and by the complete absence of a neck at the anterior end.

Cell oblong-ovoid, tapering posteriorly to a short tail, anterior end truncate-rounded, 35μ long $\times$ 17μ wide. Flagellum about body length. Periplast bearing prominent spiral rows of small warts or verrucae, about 17 rows being visible at a time. Paramylum forming two rings, one on each side of the cell. Chloroplasts parietal, numerous, discoid, small, 1.5μ in diameter.

A *L. ovo* var. *ovo* haec varietas differt: posteriore cuneatim caudata, membrana verrucis minutis seriatim ornata.

A. L. quadrato (Kuff.) Conrad dimensione minore, forma ovoide, ore haud eminenti haec varietas facile recognoscenda.

Cellula oblongo-ovoidea, posteriore in caudam brevem angustata, anteriore truncato-rotundata, flagello aequilongo praedita, 35μ longa, 17μ lata. *Membrana* verrucis minutis seriatim ornata; 17 series simul visibiles. *Paramyla* annularia, utrinque lateraliter sita. *Chlorophora* parietalia, numerosa, discoidea.

Habitat: Malacca in locis oryzae paludosis (Prowse 239a).

(xiii) ***Lepocinclis acicularis*** Francé (Fig. 2t).

Cell fusiform, tapering to a short wedge-shaped tail at the posterior end, notched at the anterior end, 23μ long $\times$ 8μ wide. Flagellum about $\frac{1}{2}$ body length. Periplast hyaline, steeply, spirally striate to the right. Paramylum two large rings one on each side. Chloroplasts parietal, discoid, many.

Collected from a drainage channel, Malacca, occasional.

Reported from Hungary and the Netherlands.

(xiv) ***Lepocinclis steinii*** Lemm. (emend. Conrad) (Fig. 2u).

Cell fusiform to ellipsoidal, narrowing towards both ends, tapering to a sharp conical tail at the posterior end, slightly truncate and notched at the anterior end, 30μ long $\times$ 10μ wide, tail 9μ long. Periplast hyaline to yellowish, with well-marked, costate, longitudinal striations. Flagellum about $1\frac{1}{2}$ body length. Chloroplasts parietal, discoid, numerous. Paramylum 2 rings, one on each side.

Collected from fish-ponds, Malacca. Cosmopolitan in distribution.

(xv) ***Lepocinclis marsonni*** Lemm. emend. Conrad (Fig. 2w, x).

Cell elongate fusiform, bearing a long sharp tail at the posterior end, and drawn out to a narrow straight neck at the anterior end, $33\text{--}60\mu$ long $\times$ $10\text{--}12\mu$ wide. Flagellum about $\frac{3}{4}$ body length. Periplast hyaline, faintly striate longitudinally. Chloroplasts parietal, discoid, numerous. Paramylum 2 large, laterally-placed rings.

Collected from padi swamps, and fish-ponds in several localities in Malaya. Common. Cosmopolitan in distribution.

(xvi) ***Lepocinclis salina*** Fritsch (Fig. 2b).

Cell broadly ovate, flattened somewhat, broadly rounded at the posterior end, slightly narrower at the anterior end, 50μ long $\times$ 43μ wide. Flagellum up to twice body length. Periplast spirally striate to the left. Paramylum numerous small discs, sometimes with hollow centres. Chloroplasts parietal, numerous, discoid, but often so close together that they become polygonal.

Collected from padi swamps and fish-ponds, Malacca, common. Cosmopolitan in distribution.

This species closely resembles *L. texta* (Duj.) Lemm. (vide) but can easily be distinguished by the direction of the striations. The paramylum granules are somewhat different as well, being distinctly discoid, and not ovoid.

Colacium Ehrenberg 1833

Cells gregarious or colonial, living attached to small crustacea or insects, often forming dendroid colonies. The individual cells are attached by the anterior end, as can be seen by the position of the stigma, the means of attachment being a gelatinous stalk, which may be branched in dendroid fashion to hold several cells; the base of the stalk is usually discoid. Flagellate stages only occur during reproduction, and closely resemble *Euglena*, especially small forms with discoid chloroplasts.

Colacium vesiculosum Ehr. (Figs. 2y, z).

Cells fusiform to ovoid, solitary, or 2–4 together, $13\text{--}20\mu$ long $\times$ $9\text{--}11\mu$ wide, attached by short gelatinous stalks to small crustacea. Chloroplasts parietal, several, ovoid discs without pyrenoids. Stigma usually quite clearly visible at the anterior end. Paramylum not observed. Flagellate stage not seen.

Collected from a fish-pond in Malacca, where it occurs quite frequently. Widespread in distribution.

I have included *Euglena cyclopicola* Gicklhorn (*Colacium cyclopicola* (Gicklh.) Bourr.) under *Euglena* because it so readily leaves its host without undergoing reproduction, and can reattach itself again. The distinction is a slender one, but names are after all artificial. It is of interest that the two species do not occur in the same pond, but in different ones, where they are frequent.

Phacus Dujardin 1841

Cells solitary, free-swimming, not metabolic, very much flattened dorsi-ventrally, generally ovoid or ellipsoidal, often with a marked tail-piece. Periplast firm, usually distinctly striate, longitudinally or spirally, ribbed or with verrucae or hooks in some species. Flagellum single, of varying length. Vacuolar system a cytostome and reservoir. Stigma prominent, near the reservoir. Chloroplasts parietal, numerous discoid. Pyrenoids absent. Paramylum discoid, ring-shaped or lenticular, usually 1–2. Holophytic, but saprophytic colourless forms have been reported.

Key to the species

- A. Section *Proterophacus*: the periplast bears fine striations, not ribs, and the cells are usually somewhat flattened, dorsi-ventrally.
- B. Section *Pleuraspis*: the periplast is distinctly ribbed (costate) and the cells more massive in cross-section.
- C. Section *Acanthopeltis*: the periplast bears longitudinal or spiral rows of wart-like or hooked excrescences.

A. *Proterophacus*

- 1. Cells without any tail-piece, the posterior end being completely rounded, the cell outline being round or elliptical. Generally flattened dorsi-ventrally 2.
- 1. Cells bearing at the posterior end a blunt, very short, wart-like outgrowth instead of a tail-piece 6.
- 1. Cell posterior bearing a very short, but sharp, tail-piece, hardly set off from the main body 7.
- 1. Cell bearing a well-marked tail-piece, straight or bent, more or less short and pointed, clearly set off from the main body 8.
- 1. Cell bearing a long thin pointed tail-piece, markedly set off from the main body, and about body length 14.
- 2. Cells almost circular in outline, large 3.
- 2. Cells elongate oval, about twice as long as broad, small .. 4.
- 3. Cells flattened. Paramylum a single large disc, and sometimes many very small ones as well. $45-55 \times 40-48\mu$
(i) *Ph. Stokesii*.
- 3. Cell much thicker. Paramylum several medium-sized sub-spherical granules with hollow centres. $55 \times 46\mu$
(ii) *Ph. Lefevrei*.
- 4. Cell not grooved throughout its length 5.
- 4. Cell grooved throughout its length. Paramylum 1 small ring. $19 \times 8\mu$ (iv) *Ph. pusillum*.
- 5. Cell longitudinally striate, paramylum two oval discs placed longitudinally $18 \times 8.5\mu$ (iii) *Ph. Wettsteini*.
- 5. Cell spirally striate, paramylum two rings placed longitudinally. $25 \times 14\mu$ (v) *Ph. dangeardii*.
- 6. Cell twice as long as broad, cylindrical. Paramylum a single large cylinder. $20 \times 7-10\mu$ (vi) *Ph. granum*.

6. Cell elongate ovoid, narrowing posteriorly. Paramylum a large cylinder nearly filling the cell, with a smaller one lying posterior to it. $22 \times 8\mu$... (vii) *Ph. polytrophos*.
6. Cell ovate, broader than preceding, ventral face inrolled to form a groove. Paramylum two laterally placed discs or rings. $22-26 \times 14-18\mu$ (viii) *Ph. oscillans*.
6. Cell almost quadrate ovate, paramylum two large curved plates just within the chloroplasts. $12.5 \times 11\mu$
(ix) *Ph. agilis*.
7. Cells flattish, elliptical or plano-convex in cross-section, broadly ovoid in outline (x-xii) *Ph. acuminatus* & vars.
7. Cells triangular in cross-section, ovoid in outline, twice as long as broad. $22-28 \times 11.5-13\mu$ (xiii) *Ph. trifacialis*.
8. Cells in section flattened, elliptical, plano-convex, or concavo-convex, not markedly twisted 9.
8. Cell in section markedly triangular, with a dorsal ridge, outline broadly ovoid, tail prominent, deflected to one side. $80 \times 45\mu$ (xxiv) *Ph. triquetus*.
8. Cell in section bearing three radiating wings spirally twisted, in outline smoothly orbicular, with a sharply pointed tail. $22 \times 16\mu$ (xxv) *Ph. tricarinatus*.
8. Cell section of two unequally thickened lobes, twisted on each other, cell outline ovate, tail pointed, sharply bent to one side. $30-40 \times 25-30\mu$ (xvii) *Ph. anomalus*.
8. Cell of two wings folded back towards dorsal side, outline irregularly elongate ovate, markedly twisted. $45 \times 18\mu$
(xviii) *Ph. raciborskii*.
9. Cell outline usually smooth 10.
9. Cell outline usually notched 13.
9. Cell outline broadly ovoid, bearing a distinct hook on the left lateral edge. Tail stout, sharp-pointed, inclined. Paramylum 1 large disc. $102-110 \times 65-70\mu$
(xxiii) *Ph. unidentatus*.
10. Body of cell distinctly longer than broad (about $1\frac{1}{2}$ times) 11.
10. Body of cell nearly as broad as long, or broader 12.
11. Cell ovate, flattened, slightly twisted, tail straight, paramylum, one large disc. $45 \times 22\mu$ (xiv) *Ph. caudatus*.

11. Cell ovoid, convexo-concave in section, tail bent to one side or even hooked, paramylum two unlike concentric discs, one lying on the other. $37-45 \times 20-25_{\mu}$
(xxii) *Ph. hamatus*.
12. Cell somewhat rounded—triangular in outline, wider posteriorly, tail broad wedge-shaped, obliquely inclined, paramylum two large discs sometimes with hollow centres. $37 \times 29_{\mu}$ (xvi) *Ph. angulatus*.
12. Cell roundish in outline, wider to the posterior, tail short, sharp, very abruptly turned to one side, paramylum two unequal lateral discs. $23-28 \times 22-25_{\mu}$
(xv) *Ph. curvicauda*.
12. Cell almost perfectly circular, tail relatively short, sharp, turned to one side, paramylum one large central disc. $34 \times 30_{\mu}$ (xix) *Ph. circulatus*.
12. Cell broadly ovate, flattened, tail slender, sharp-pointed, turned slightly to one side, paramylum one large central disc. $43 \times 30_{\mu}$ (xx) *Ph. platealea*.
12. Cell broadly ovoid to sub-orbicular, slightly asymmetrical, tail stout, sharp-pointed, turned obliquely to one side, paramylum one or two discs or rings. $60 \times 50_{\mu}$
(xxi) *Ph. pleuronectes*.
13. Cell rounded trapezoidal in outline, broadest to the posterior, tail short, thick, inclined to one side, sides bearing several notches, paramylum 1-2 large central discs. $33-30_{\mu}$
(xxvi) *Ph. Myersi*.
13. Cell rounded trapezoidal in outline, broadest and very abrupt at the posterior end, tail very stout, inclined obliquely upwards in the dorsal direction, paramylum 1 large central disc or ring. $50-55 \times 35-37_{\mu}$ (xxvii) *Ph. onyx*.
14. Cell body not twisted 15.
14. Cell body markedly twisted 16.
15. Cell oval, tail long and curved, paramylum 1 central disc. $95-140$ (with tail) $\times 35-50_{\mu}$
(xxviii) *Ph. longicauda* var. *rotunda*.
15. Cell elliptical, tail long and distinctly bent to kinked, paramylum numerous small discs. $90 \times 37_{\mu}$ (with tail)
(xxxi) *Ph. ranula*.

16. Cell twisted once through 180° , paramylum one large central disc. $80-85 \times 27-36\mu$ (xxix) *Ph. tortus*.
16. Cell twisted through $1\frac{1}{2}$ to 2 turns showing at least three twists, paramylum 1 large central disc. $100 \times 42\mu$
(xxx) *Ph. helicoides*.

B. Pleuraspis

1. Cell ovoid, widely elliptical in cross-section, costae spiralling to the right. $32 \times 14\mu$ (xxxii) *Ph. pyrum*.
1. Cell oval, much flattened dorso-ventrally, costae spiralling to the right. $37 \times 17\mu$ (xxxiii) *Ph. pseudonordstedtii*.

C. Acanthopeltis

1. Cell wall smooth. $26 \times 19\mu$ (xxxv) *Ph. glaber*.
1. Cell wall bearing longitudinal rows of blunt warts. $25-36 \times 15-23\mu$ (xxxiv) *Ph. suecicus*.
1. Cell wall bearing longitudinal rows of down-curved hooks. $48 \times 33\mu$ (xxxvi) *Ph. horridus*.

(i) *Phacus stokesii* Lemm. (Fig. 4l).

Cell suborbicular, distinctly flattened, with a central groove running the full length of the cell, at the posterior end bearing a very small swelling, $45-55\mu$ long $\times$ $40-48\mu$ wide. Flagellum about body length. Periplast hyaline, longitudinally striate. Paramylum one large disc, and sometimes many very small granules as well. Chloroplasts discoid, parietal, numerous. Stigma light crimson, distinctly cup-shaped.

Collected from padi swamps, Malacca, fairly common.

Reported also from U.S.A., Poland, China and Java.

(ii) *Phacus lefevrei* Bourelly (Fig. 4m).

Cell suborbicular, much less flattened than the previous species, with the central groove only reaching $\frac{3}{4}$ length of the cell, and ending posteriorly in a broad, shallow swelling, 55μ long $\times$ 46μ wide. Flagellum about body length. Periplast hyaline, longitudinally striate. Chloroplasts parietal, discoid, numerous. Paramylum several medium sized subspherical granules sometimes with hollowed centres. Stigma large deep crimson, granular.

Collected from padi swamps, Malacca, occasional.

Reported also from Guadelope.

Close to *Ph. stokesii* but differing in being much less flattened, the groove being shorter, and by the nature of the paramylum and the stigma.

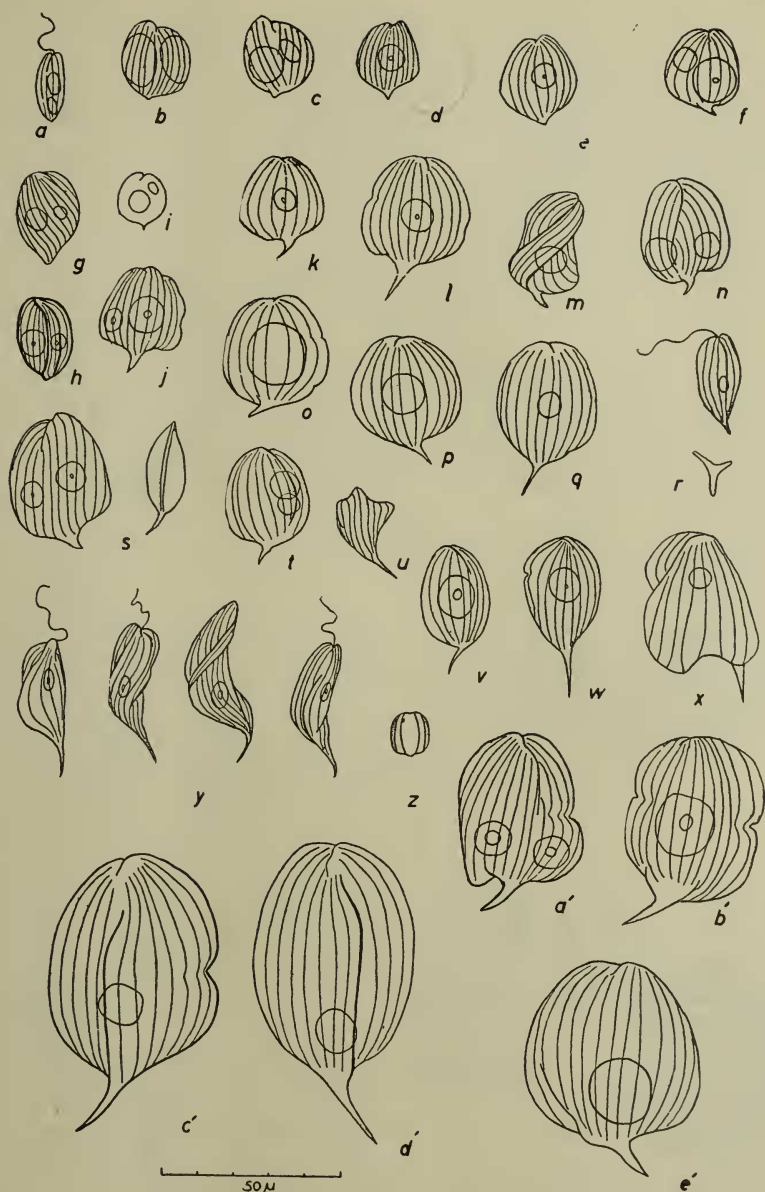


FIGURE 3

Malayan species of *Phacus* Dujardin:—

a, *P. wetsteinii* Drez.; b, *P. acuminatus* Stokes var. *javana* (Poch.) Hüber-Pest.; c, *P. acuminatus* var. *discifera* (Poch.) (Hüber-Pest.; d-e, *P. acuminatus* Stokes; f, k, *P. curvicauda* Swirenko; g-h, *P. oscillans* Klebs; i, *P. circulus* Poch. small form; j, o, *P. myersi* Skv.; l, a₁b₁ *P. onyx* Poch.; m-n, x, *P. anomalus* Fritsch & Rich; p, *P. circulus* Poch.; q, *P. platalea* Drez.; r, *P. trifacialis* Prowse; s, *P. angulatus* Poch.; u, y, *P. raciborskii* Drez.; v, *P. hamatus* Poch.; w, *P. caudatus* Hübner; z, *P. agilis* Skuja; c₁-d₁, *P. triqueter* (Ehr.) Dujardin; e₁, *P. pleuronectes* (O.F.M.) Duj.

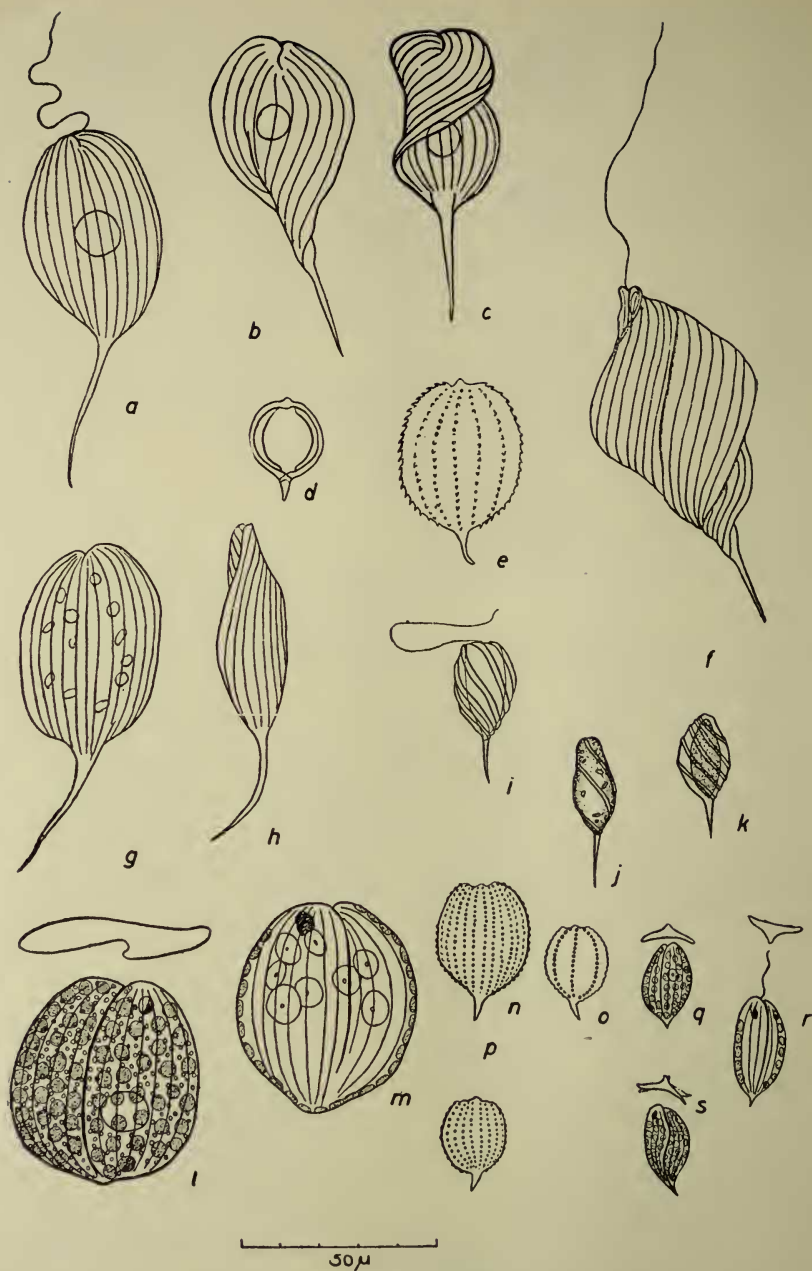


FIGURE 4

Malayan species of *Phacus* Dujardin:—

a, *P. longicauda* (Ehr.) Duj. var. *rotunda* (Poch.) Hüber-Pest; b-c, *P. tortus* (Lemm.) Skv.; d, *P. glaber* (Défl.) Poch.; e, *P. horridus* Poch.; f, *P. helikoides* Poch.; g-h, *P. ranula* Poch.; i-j, *P. pseudonordstedtii* Poch.; k, *P. pyrum* (Ehr.) Stein; l, *P. stokessii* Lemm.; m, *P. lefevrei* Bourrelly; n-p, *P. suecicus* Lemm.; q-s, *P. trifacialis* Prowse.

(iii) **Phacus wettsteinii** Drez. (Fig. 3a).

Cell elongate oval, rounded at both ends or slightly tapered at the posterior end, apical groove reaching to the posterior end, 18μ long $\times$ 8.5μ wide. Flagellum about body length. Periplast hyaline, longitudinally striate. Paramylum two large oval discs placed longitudinally in the cell. Chloroplasts a few large discs, parietal.

Collected from fish-ponds, Malacca, occasional.

Reported from Poland and Czechoslovakia.

(iv) **Phacus pusillus** Lemm. (Fig. 5e).

Cell elongate oval, rounded at both ends, slightly flattened, with a wide groove running the full length of the cell, slightly twisted, 19μ long $\times$ 8μ wide. Flagellum about $\frac{1}{2}$ body length. Periplast finely striate longitudinally. Paramylum 1–2 small rings. Chloroplasts parietal, small, discoid, numerous.

Collected from padi swamps, Malacca, occasional.

Reported from Europe.

(v) **Phacus dangeardii** Lemm. (Fig. 5d).

Cell elongate oval, flattened, rounded at both ends, with no longitudinal groove, 25μ long $\times$ 14μ wide. Flagellum about body length. Periplast spirally striate. Paramylum two rings placed longitudinally. Chloroplasts parietal, discoid, numerous.

Collected from padi swamps, Malacca.

Reported from France.

(vi) **Phacus granum** Drez. (Fig. 5g).

Cell nearly cylindrical, rounded anteriorly and ending at the posterior end in a very short conical swelling; apical groove very short. 20μ long $\times$ 7 – 10μ wide. Flagellum about body length. Periplast delicately striate longitudinally. Paramylum a single large cylinder with rounded ends, placed usually longitudinally.

Collected from padi swamps, Malacca.

Reported from Germany, Poland and Bali.

(vii) **Phacus polytrophos** Pochmann (Fig. 5f).

Cell elongate ovoid, narrowing towards the posterior end, slightly obliquely truncate at the anterior end, 22μ long $\times$ 8μ wide. Flagellum about body length. Periplast delicately spirally striate towards the left. Paramylum a large cylinder filling most of the cell and a smaller one lying posterior to it. Chloroplasts parietal, discoid, numerous.

Collected from fish-ponds, Malacca, occasional.

Reported from Russia, Poland, China and Germany.

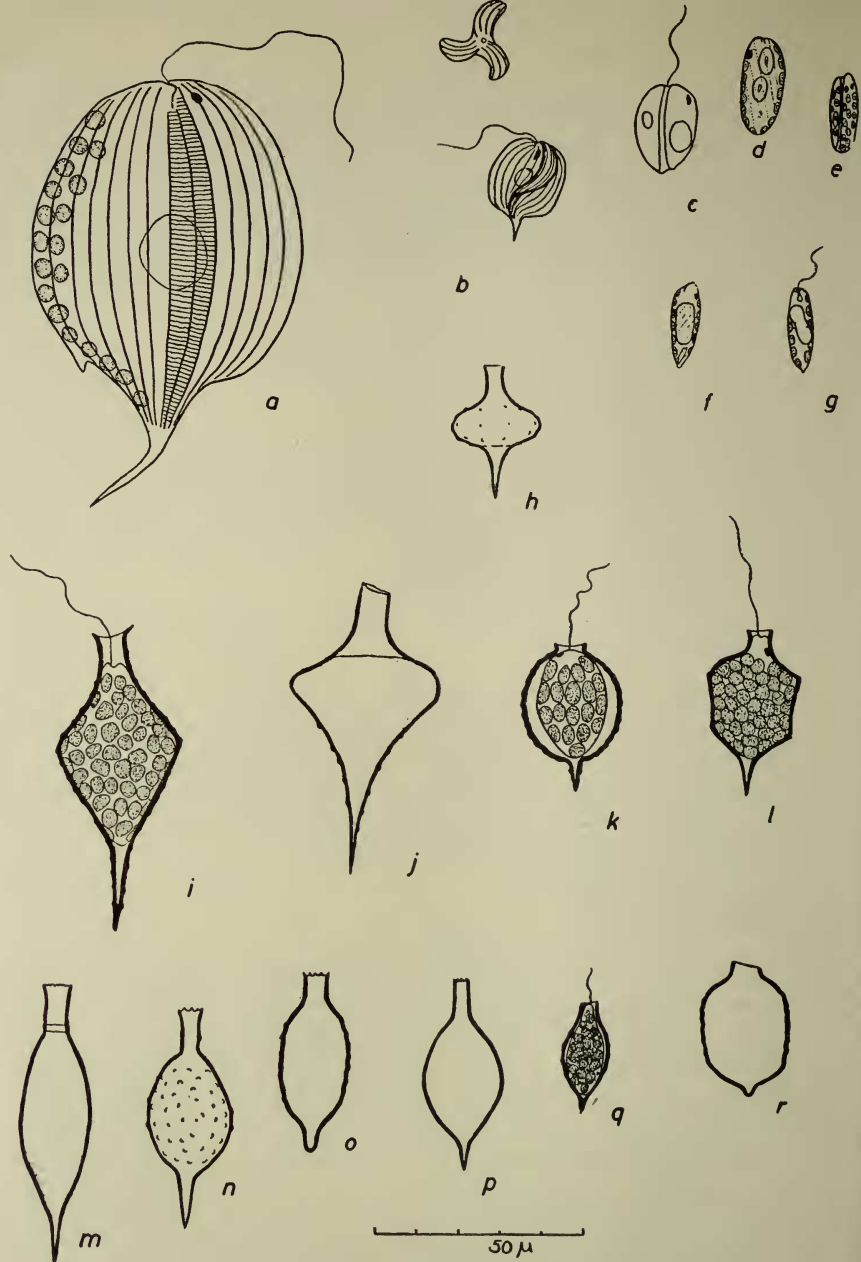


FIGURE 5

Malayan species of *Phacus* Dujardin:—

a, *P. unidentatus* Prowse; b, *P. tricarinatus* Prowse; c, *P. oscillans* Klebs; d, *P. dangeardii* Lemm.; e, *P. pusillus* Lemm.; f, *P. polytrophos* Poch.; g, *P. granum* Drez.

Strombomonas Défl. species in Malaya:—

h, *S. schaunslanii* (Lemm.) Défl.; i-j, *S. gibberosa* (Playf.) Défl.; k, *S. praeliariis* (Palmer) Défl. var. *brevicollaris* Prowse; l, *S. girardiana* (Playf.) Défl.; m-p, *S. australica* (Play.) Défl.; q, *S. fluvialis* (Lemm.) Défl.; r, *S. deflandrei* (Roll) Défl.

(viii) **Phacus oscillans** Klebs (Figs. 3g, h, 5c).

Cell ovate, broadly rounded at the anterior end, narrowed towards the posterior, ending in a very short blunt projection; ventral face inrolled forming a groove running obliquely the full length of the cell; $22-26\mu$ long $\times$ $14-18\mu$ wide. Periplast spirally striate. Flagellum about body length. Paramylum two discs or rings. Chloroplasts parietal, small round discs, numerous. The cell swims very rapidly rotating about the long axis.

Collected from fish-ponds in various localities in Malaya. Common. Cosmopolitan in distribution.

The Malayan specimens are relatively broader than described elsewhere, but the species is a variable one, and it is doubtful if this apparent difference is of any real significance.

(ix) **Phacus agilis** Skuja (Fig. 3z).

Cells quadrate-ovate in outline, slightly narrower at the anterior end and notched, and with a very short wart-like tail at the posterior end, 12.5μ long $\times$ 11μ wide. Flagellum about body length. Paramylum two large curved discs lying just within the chloroplasts. Chloroplasts parietal, two large discs lying just within the periplast, lateral.

Collected from fish-ponds, padi swamps and drains in various localities in Malaya.

Reported from Europe and Indonesia.

This is a very characteristic, if slightly variable species.

(x) **Phacus acuminatus** Stokes (Figs. 3d, e).

Cell broadly ovoid, bearing posteriorly a very short, broad, wedge-shaped, but pointed tailpiece, narrowing towards the anterior end, $22-26\mu$ long $\times$ $17-22\mu$ wide. Flagellum about body length. Periplast longitudinally striate. Paramylum one or two rings. Chloroplasts parietal, discoid, numerous.

Collected from fish-ponds, Malacca.

Reported from U.S.A., Russia and S. Africa.

(xi) **Ph. acuminatus** var. **disciferus** (Pochmann) Hüber-Pestalozzi (Fig. 3c).

Differs from the type in being rounder, slightly narrowed towards the anterior, bearing on the posterior end a very short, blunt wedge-shaped tail, and in the two large unequal imperforate discs, the larger in the middle, the smaller lying excentrically. 22μ long $\times$ 20μ wide.

Collected from fish-ponds, Malacca, common.

Reported from France.

- (xii) **Ph. acuminatus** var. **javanus** (Pochmann) Hüber-Pestalozzi (Fig. 3b).

Differing from the preceding by the apical groove reaching nearly to the posterior end, and the two equal, symmetrically placed paramylum rings. 23μ long $\times$ 20μ wide.

Collected from padi swamps, Malacca, common.

Reported from Java.

The above varieties have been separated by both Pochmann and Hüber-Pestalozzi, and I have done likewise, but it is uncertain to what extent such a separation is justified.

- (xiii) **Phacus trifacialis** Prowse sp. nov. (Figs. 3r, 4q-s).

Distinguished from the other similarly sized caudate species by the distinct ridge running the full length of the dorsal surface, and by the characteristic triangular cross-section.

Cell ovoid, gradually narrowing to a point posteriorly, rounded anteriorly, $22-28\mu$ long $\times$ $11.5-13\mu$ wide; a distinct ridge runs the full length of the dorsal face, so that in transverse section the cell is like a broad shallow triangle, with the ventral surface slightly hollowed; sometimes the cell is twisted throughout its length. Flagellum about half body length. Paramylum granule a single small ring, usually central. Chloroplasts parietal, small, 1.5μ in diameter.

Inter omnes *Phaci* flagellati caudatique, sectione transversali triangularis carinis inaequilbus haec species differt.

Cellula ambitu ovoidea, posteriore paulatim angustata acuta, anteriore rotundata flagello dimidio longo praedita paulo torta vel non, dorso per totam longitudinem conspicue uni-carinata sectione transversali triangulata, ventre leviter concava, $22-28\mu$ longa, $11.5-13\mu$ lata.

Paramylum unicum, plerumque centrale, annulare. *Chlorophora* parietalia, parva, 1.5μ in diam.

Habitat: Malacca in locis oryzae paludosis et in piscinis (Prowse 186a, 192a).

- (xiv) **Phacus caudatus** Hübner (Fig. 3w).

Cells ovate, flattened, but often slightly twisted, so that one side seems more convex than the other, giving an asymmetrical appearance; occasionally there may be a small notch on one side; posterior end tapered to form a well-marked, sharp pointed tail-piece, the anterior end broadly rounded, 45μ long (including tail) $\times$ 22μ wide, tail 15μ long. Flagellum about body length. Periplast longitudinally striate. Paramylum one large ring, with sometimes a smaller one as well. Chloroplasts parietal, discoid, numerous.

Collected from padi swamps and fish-ponds, Malacca.

Reported from Europe, Asia and America.

This is a somewhat variable species, and the presence of a lateral notch in some specimens is no justification for separating them off as a variety.

(xv) **Phacus curvicauda** Swirenko (Figs. 3f, k).

Cell roundish in outline, sometimes slightly wider than longer, narrowing towards the anterior end, bearing at the posterior end a short sharp tail turned markedly to one side. Apical groove variable in length, ranging from short to nearly the full length of the cell. $23\text{--}28\mu$ long $\times 22\text{--}25\mu$ wide. Periplast longitudinally striate. Paramylum usually two unequal discs lying laterally. Flagellum about body length. Chloroplasts parietal, discoid, numerous.

Collected from fish-ponds and padi swamps, Malacca. Cosmopolitan in distribution, including Indonesia.

This is distinctly variable species, but always with the sharply bent tail-piece. The length of the apical groove varies even within the same population, so it cannot be considered a satisfactory diagnostic character.

(xvi) **Phacus angulatus** Pochmann (Fig. 3s).

Cell somewhat rounded triangular in shape, broader to the posterior end, with a short, wide, curved tail; narrower anteriorly; 37μ long $\times 29\mu$ wide. Flagellum about body length. Periplast longitudinally striate. Paramylum two large discs, sometimes slightly hollowed in the centres. Chloroplasts parietal, rounded, numerous.

Collected from padi swamps, Malacca.

Reported also from Burma.

(xvii) **Phacus anomalus** Fritsch & Rich (Figs. 3m, n, x).

Cell body consisting of two unequal halves, one half being wider than the other, twisted in opposite directions; in outline the cell may appear ovate, or sometimes narrower at the anterior end, and bearing posteriorly a sharp pointed tail markedly set off from the main body of the cell, $30\text{--}40\mu \times 25\text{--}30\mu$ wide, thickness of narrower wing $9\text{--}10\mu$, that of the wider wing being $6\text{--}7\mu$, the wings being unequal in thickness as well as in breadth. Flagellum about body length. Striations of the periplast longitudinal, following the bends of the two parts. Paramylum one or two thickish discs. Chloroplasts parietal, discoid, numerous.

Common in the lake of the Botanic Gardens, Singapore, fish-ponds, padi swamps, rain pools and drains, Malacca and elsewhere.

Reported from S. Africa, Europe and Java.

This is unmistakable species which cannot be confused with any other, especially when seen in the living state.

(xviii) **Phacus raciborskii** Drez. (Figs. 3u, y).

Cell irregularly elongate-ovate in outline, very variable according to the aspect; the cell body is made up of two wings folded back towards the dorsal surface, and tapering posteriorly to a sharp pointed, often curved tail, the whole cell being markedly twisted throughout its length; from the ventral face the cell may display a long twisted keel, and from the dorsal side a similar hollow groove; 45μ long $\times$ 18μ wide. Flagellum about body length. Striations of the periplast following the curves of the wings longitudinally. Paramylum usually one, occasionally two hollowed discs. Chloroplasts parietal, discoid, numerous.

Common in the lake of the Botanic Gardens, and fish-ponds, padi swamps in various localities in Malaya.

Reported from France, Poland and Hungary.

This species is so characteristic, that anyone who has seen it, especially in the living state, could not confuse it with any other species.

(xix) **Phacus circulatus** Pochmann (Figs. 3p, i).

Cell almost perfectly round with a relatively short, sharp tail turned to one side, 34μ long (with tail) $\times$ 30μ wide. Flagellum about body length. Periplast longitudinally striate. Apical groove reaching to about halfway. Paramylum one large central disc. Chloroplasts parietal, discoid, numerous.

Collected from padi swamps, fish-ponds, Malacca.

Reported from Germany and Poland.

A much smaller form (fig. 3i), $13\mu \times 16\mu$ has occurred in the same waters, but I have been chary of separating it as a variety, as we know too little about nutritional and growth forms.

(xx) **Phacus platalea** Drez. (Fig. 3q).

Cell broadly ovate, flattened, with a prominent sharp tail inclined to one side; apical groove reaching up to halfway; 43μ long (with tail) $\times$ 30μ wide, tail 9μ long. Flagellum about body length. Periplast longitudinally striate. Paramylum one large central disc. Chloroplasts parietal, discoid, numerous.

Collected from fish-ponds and padi swamps, Malacca.

Reported from Poland and France.

(xxi) **Phacus pleuronectes** (O.F.M.) Dujardin (Fig. 3e₁).

Cell broadly ovoid to suborbicular in outline, slightly asymmetrical, produced posteriorly to form a sharp pointed tail turned obliquely to one side, broadly rounded anteriorly, 60μ long $\times$

50 μ wide. Flagellum body length or longer. Periplast longitudinally striate. Paramylum one or two discs, often hollowed to form rings. Chloroplasts parietal, discoid, numerous.

Collected from the lake in the Botanic Gardens, Singapore, fish-ponds and padi swamps, Malacca. Cosmopolitan in distribution.

This is a common and rather variable species.

(xxii) **Phacus hamatus** Pochmann (Fig. 3v).

Cell ovoid, narrowing at both ends, but slightly wider in the posterior half, bearing a sharp-pointed tail, usually somewhat hooked and turned to one side, dorsal surface convex, ventral surface concave, 37–45 μ long $\times$ 20–25 μ wide, tail 8–12 μ long. Flagellum 1½ times body length. Periplast longitudinally striate. Paramylum usually two unequal concentric discs, one lying on top of the other so that superficially they look like a ring. Chloroplasts parietal, discoid, numerous.

Collected from fish-ponds, padi swamps and from the lake in the Botanic Gardens, Singapore, common.

Reported also from Europe, Russia and Argentina.

(xxiii) **Phacus unidentatus** Prowse **sp. nov.** (Fig. 5a).

Allied to *Ph. pleuronectes* (O.F.M.) Duj. but differing in the tooth on the left lateral edge.

Cells broadly ovoid in outline, bearing a distinct hook on the left lateral edge towards the posterior end (when viewed from the dorsal face), tapering towards the posterior end to form a stout, sharp pointed tail, obliquely turned to the same side as the hook; anterior end broadly rounded; flagellum about body length; cell slightly hollowed ventrally, slightly convex dorsally, 102–110 μ long (with tail) $\times$ 65–70 μ wide; tail 15–30 μ long. Longitudinal striations of the periplast prominent, with finer cross-connections. Paramylum body a single large, central disc. Chloroplasts parietal, discoid, 3–4 μ in diameter.

A *Ph. pleuronectes* (O.F.M.) Duj., cui affinissima, cellulis in laevum unidentatis, flagellis multo longioribus haec species facile distinguenda.

Cellula ambitu late ovoidea, posteriore caudiculata, anteriore rotundato-truncata, flagello eae fere aequilongo praedita, supra basin sinistro unidentata, ventre concaviuscula, dorso leviter convexa, cum caudicula 102–110 μ longa, 65–70 μ lata; caudicula in laevum oblique flexa, cuneata, apice acuta, 15–30 μ longa. *Membrana* longitudinaliter prominente striata, reticulationibus gracillimis praedita. *Paramylum* magnum, unicum, centrale, disciforme. *Chlorophora* parietalia, discoidea 3–4 μ in diam.

Habitat: Malacca, in locis oryzalibus paludosis (Prowse 239b).
(xxiv) **Phacus triqueter** (Ehr.) Dujardin (Figs. 3c₁, d₁).

Cells broadly ovoid, rarely with a constriction at one side, narrowed asymmetrically posteriorly to form a prominent, sharp pointed tail, slightly inclined to one side and deflected upwards from the dorsal surface, broadly rounded at the anterior end, with a prominent cleft marking the cytostome; on the dorsal surface a high ridge runs the full length of the cell, so that in cross-section it is triangular, slightly hollowed on the ventral surface; 80μ long (with tail) $\times$ 45μ wide, tail 25μ long. Flagellum about $1\frac{1}{2}$ body length. Periplast longitudinally striate. Paramylum one or two large discs or rings. Chloroplasts discoid, parietal, numerous.

Collected from the lake in the Botanic Gardens, Singapore, and from fish-ponds and padi swamps, Malacca.

Reported from Europe, India, Java and Venezuela.

(xxv) **Phacus tricarinatus** Prowse sp. nov. (Fig 5b).

Allied to *Ph. Warszewiczii* Drez., but differing in that the striations run strictly longitudinally down the wings and the edges of the wings, so that outline is quite smooth, and not crenulate in that species, which has oblique striations.

Cell smoothly orbicular in outline, ending posteriorly in a wedge-shaped tail; anterior end broadly rounded. Cell body consisting of three equally-radiating longitudinal wings, slightly twisted from left to right in the posterior direction; 22μ long $\times$ 16μ wide. Flagellum about body length. Striations of the periplast running longitudinally, both along the ridges and in the hollows between the wings. Paramylum granules usually one, sometimes two central discs. Chloroplasts parietal, small, discoid, 1.5μ in diameter.

A *Ph. Warszewiczii* Drez. cui affinissima sed striationibus in carina et ejusdem margine verticalissimis (non obliquis), cellulis ambitu integerrimis (non crenulatis) haec species differt.

Cellula ambitu orbicularis, posteriore cuneata, anteriore late rotundata, flagello aequilongo praedita, in tres carinas inter se fere aequidistantes ad dextrum paulo reflexas vel tortas longitudinaliter divisa, verticaliter striata, 22μ longa, 16μ lata. *Granula paramylonica* plerumque singula, interdum bina, disciformia centraliter sita. *Chlorophora* parietalia, parva, discoidea, 1.5μ in diam.

Habitat: Malacca, in locis oryzalibus paludosis (Prowse 239c).
(xxvi) **Phacus myersi** Skvortzow (Figs. 3j, o).

Cell rounded, trapezium shaped, broadest near the posterior end, bearing a short thick, obliquely inclined tail; cell narrower

towards anterior end, sometimes rounded truncate; both sides distinctly notched; 33μ long $\times$ 30μ wide, tail 4–5 μ long. Flagellum body length. Periplast longitudinally striate. Paramylum 1–2 large central discs or rings. Chloroplasts parietal, discoid, numerous.

Collected from padi swamps, Malacca.

Reported from S. China.

This is a slightly variable species, close to *Ph. undulatus* (Skv.) Pochmann in its notched sides, but it can always be distinguished by its much wider and trapezoidal shape.

(xxvii) **Phacus onyx** Pochmann (Fig. 31, a_1 , b_1).

Cell round, trapezoidal, broadest and somewhat abrupt at the posterior end, bearing a stout sharp tail, curved upwards from the dorsal surface and slightly to one side, anterior end rounded; one or both sides notched, 50–55 μ long $\times$ 35–37 μ wide, tail 14–17 μ long. Flagellum over body length. Periplast longitudinally striate. Paramylum one large central disc or ring, more rarely two smaller ones. Chloroplasts parietal, discoid, numerous.

Collected from the lake of the Botanic Gardens, Singapore, and from fish-ponds and padi swamps, Malacca.

Reported from Europe, U.S.A. and Indonesia.

This comes close to the preceding species, from which it differs by the much larger size, and the very stout, outstanding, tailpiece.

(xxviii) **Phacus longicauda** (Ehr) Dujardin var. **rotundus** Pochmann) Hüber-Pestalozzi (Fig. 4a).

Cell oval, slightly asymmetrical, ending posteriorly in a long sharp tail, more or less curved; anterior end rounded; 35–140 μ long (with tail) $\times$ 35–50 μ wide, tail 40–60 μ long. Flagellum about body length. Periplast longitudinally striate. Paramylum one large central disc. Chloroplasts parietal, discoid, numerous.

Collected from the lake in the Botanic Gardens, and from fish-ponds and padi swamps, Malacca, common. Cosmopolitan in distribution, including Java.

Although a number of varieties of *Ph. longicauda* have been described, this is the only form which has so far been reported from Malaya, oval in shape, and with the tail about as long as the body.

(xxix) **Phacus tortus** (Lemm.) Skvortzow (Figs. 4b, c).

Close to *Ph. longicauda* but twisted about the longitudinal axis once through 180°, so that the outline may vary from ovate-fusiform to almost rectangular, with the anterior end appearing very truncate; bearing posteriorly a long sharp tail; 80–85 μ long (with

tail) $\times$ 27–36 μ wide, tail 30–33 μ long. Flagellum body length. Periplast longitudinally striate, the striations following the twists. Paramylum one large central disc. Chloroplasts, parietal, discoid, numerous.

Collected from padi swamps, where it is very common, and from fish-ponds, Malacca.

Reported also from Europe, Asia, Java and S. Africa.

(xxx) **Phacus helikoides** Pochmann (Fig. 4f).

Close to the preceding, but the cell body is twisted through $1\frac{1}{2}$ to 2 complete turns, so that the shape is usually broadly fusiform, with usually 3 twists showing; bearing a long sharp tail at the posterior end; 95–100 μ long (with tail) $\times$ 42 μ wide, tail 25 μ long. Flagellum about $1\frac{1}{2}$ body length. Periplast striations longitudinal, but following the twists. Paramylum one large central disc. Chloroplasts, parietal, discoid, numerous.

Collected from padi swamps, Malacca, where it is common, and less frequently from fish-ponds.

Reported from Europe, Asia, including Java, and N. & S. America.

(xxxii) **Phacus ranula** Pochmann (Figs. 4g, h).

Closely related to *Ph. longicauda* but having numerous small paramylum granules, and with a distinctly kinked tailpiece. Cell elliptical in outline, flattened, slightly twisted, tapering to a long sharp, distinctly kinked tail posteriorly, rounded anteriorly; 90 μ long (including tail) $\times$ 37 μ wide, tail 37 μ long. Flagellum about body length. Periplast longitudinally striate. Paramylum several small discs. Chloroplasts parietal, discoid, numerous.

Collected from padi swamps, Malacca, occasional.

Reported from Indochina and Java.

Section Pleuraspis

(xxxiii) **Phacus pyrum** (Ehr.) Stein (Fig. 4k).

Cell ovoid, gradually narrowed posteriorly to form a long straight pointed tail, rounded, or slightly narrowed at the anterior end with an apical notch, 32 μ long (with tail) $\times$ 14 μ wide, tail 10 μ long. Flagellum about $1\frac{1}{2}$ body length. Periplast with marked ribs running spirally to the right. Paramylum two large curved plates placed just within the periplast, one on each side. Chloroplasts, discoid, numerous and small.

Common in fish-ponds and padi swamps, Malacca. Widespread in tropical freshwaters.

(xxxiii) **Phacus pseudonordstedtii** Pochmann (Figs. 4i, j).

Cell oval, flattened dorsi-ventrally, tapering posteriorly into a long sharp tail, rounded to almost truncate at the anterior end, 37μ long $\times$ 17μ wide, tail 11μ long. Flagellum $1\frac{1}{2}$ times body length. Periplast with prominent spiral ribs running to the right. Paramylum two large lateral curved plates just within the periplast. Chloroplasts numerous small discs.

Collected from padi swamps and a few fish ponds, fairly common.

Reported also from Europe, and Indonesia.

This species resembles *Ph. nordstedtii* Lemm. but it is less rounded and much flatter.

Section Acanthopeltis

(xxxiv) **Phacus suecicus** Lemm. (Figs. 4n, o, p).

Cell broadly ovoid to suborbicular, terminating in a stout, sharp-pointed tail at the posterior end, truncate or slightly retuse at the anterior end, with a central papilla through which the flagellum passes; $25-36\mu$ long $\times$ $15-23\mu$ wide. Flagellum about body length. Periplast bearing longitudinal rows of small wart-like excrescences, or verrucae, the number of rows being variable. Paramylum two large lateral curved discs lying just within the periplast. Chloroplasts numerous small circular discs.

Collected from padi swamps and fish-ponds, fairly common.

Reported from Europe, Australia and Venezuela.

(xxxv) **Phacus glaber** (Défl.) Pochmann (Fig. 4d).

Closely related to the preceding species, but quite smooth. Cell suborbicular with a short tail posteriorly, and a short papilla at the anterior end, 26μ long $\times$ 19μ wide. Flagellum about body length. Paramylum two large, laterally-placed curved discs just within the periplast. Chloroplasts numerous small discs.

Fairly common in the lake of the Botanic Gardens, Singapore, and in padi swamps and fish-ponds, Malacca.

Reported also from Germany, but probably much more widespread.

(xxxvi) **Phacus horridus** Pochmann (Fig. 4e).

Very close to *Ph. suecicus* Lemm. but with distinct hooked excrescences.

Cell broadly ovoid to subglobose, terminating posteriorly in a sharp, slightly curved tail, truncate anteriorly with a central pa-

pilla; 48μ long $\times$ 33μ wide. Flagellum about body length. Periplast bearing longitudinal rows of small hooks which point posteriorly. Paramylum two large laterally-placed curved discs, just within the periplast. Chloroplasts numerous small discs.

Fairly common in padi swamps and fish-ponds, Malacca.

Reported also from Australia and France.

Forms of several of the pigmented species of *Phacus*, but completely devoid of any chloroplasts, have occurred from time to time, and they have usually been quite actively swimming, so that they can hardly be regarded as senescent forms. On the other hand they are so obviously related to the pigmented forms, that there seems little justification in separating them off in the genus *Hyalophacus*. In any case we know very little about the nutritional requirements, and what causes the loss of chloroplasts.

Trachelomonas Ehrenberg 1833 emend. Déflandre 1930.

Cells solitary, free-swimming, somewhat metabolic, but enclosed in a firm envelope or *lorica*, with a distinct opening or *porus* through which the flagellum passes. The envelope may be spherical, oval, cylindrical or fusiform, sometimes with a distinct neck markedly set off from the rest of the body at the porus. Colour ranges from colourless to dark brown, and it may be punctate, scrobiculate, verrucose or ornamented with spines, or quite smooth. Flagellum one, usually long, projecting through the porus and neck. Vacuolar system typical of family. Paramylum granules oval or absent. Chloroplasts two to many, discoid, parietal. Pyrenoids present or absent according to species. Lives holophytically, and sometimes saprophytically.

Key to species

1. Lorica without spines 2.
1. Lorica bearing spines 10.
2. Lorica spherical in outline 3.
2. Lorica flattened, wider than long, smooth; porus with or without thickening (iii) *Tr. curta*.
2. Lorica oval to ellipsoidal 5.
2. Lorica cylindrical, with parallel sides 8.
3. Lorica smooth 4.
3. Lorica bearing irregular transverse thickenings, rugulose
(ii) *Tr. rugulosa*.
4. Lorica perfectly spherical, without any distinct neck, but sometimes with a thickening round the porus
(i) *Tr. volvocina* var. *minuta*.

4. Lorica only nearly spherical with a distinct inclined neck
(xxiv) *T. similis* var. *hyalina*.
5. Lorica without a distinct neck, only a mere thickening at the
porus at most 6.
5. Lorica with a distinct neck 7.
6. Lorica ellipsoidal, equally rounded at both ends
(v) *Tr. oblonga*.
6. Lorica cylindric-ellipsoidal, rounded at the posterior end,
somewhat flattened at the anterior end; porus bearing a
thickening, often with fine teeth
(vi) *Tr. oblonga* var. *attenuata*.
7. Neck of lorica distinctly inclined, shape of lorica oval, finely
punctate, yellowish-brown (xxiii) *Tr. similis*.
7. Neck of lorica straight, toothed; outline of lorica ellipsoidal,
membrane very rough (xxi) *Tr. crebea*.
7. Neck of lorica divided into two lobes or lips; outline oval,
membrane rough (xx) *T. scabra* var. *labiata*.
8. Lorica without a distinct neck 9.
8. Lorica bottle-shaped, with a distinct cylindrical neck, mem-
brane smooth (xxii) *Tr. volzii* var. *cylindracea*.
9. Lorica strictly cylindrical, with both ends rounded or the
anterior end flattened. Membrane punctate
(vii) *T. lacustris*.
9. Lorica shorter, tapering conically at the posterior end; mem-
brane smooth (viii) *Tr. conica*.
10. Spines short, conical, all the same size 11.
10. Spines stout, conical, much longer, all the same size, or
nearly so 15.
10. Spines variable in size, usually the posterior ones longer than
the anterior ones 18.
11. Lorica without a distinct neck 12.
11. Lorica with a distinct neck, toothed, oval in outline; spines
evenly dispersed over the body, short and uniform in
length (xiv) *Tr. mirabilis* var. *affinis*.
12. Lorica distinctly cylindrical, with sides parallel for most of
the way 13.
12. Lorica not so cylindrical, with sides not parallel 14.
12. Lorica flattened, wider than long, with 3-4 rows of a few
spines (iv) *Tr. lismorensis*.

13. Lorica cylindrical, with broadly rounded poles; spines evenly distributed, short; porus often toothed
(xii) *Tr. klebsii*.
13. Lorica larger, cylindrical, sometimes flattened at the anterior end, punctate, and set with larger, medium-sized spines, evenly distributed; porus without teeth, but sometimes thickened (xiii) *Tr. zingeri*.
14. Lorica ellipsoidal, thickly set with short, sharp, conical spines, with or without a thickening round the porus
(ix) *Tr. hispida*.
14. Lorica ellipsoidal but much longer than the preceding, thickly set with short spines; porus toothed
(x) *Tr. hispida* var. *elongata*.
14. Lorica cylindric-ellipsoidal, thickly set with short, conical spines, porus without teeth (xi) *Tr. allia*.
15. Spines evenly distributed over the whole surface of the lorica
16.
15. Spines mainly confined to the two ends 17.
16. Lorica oval, with stout spines all over, porus without teeth
(xv) *Tr. superba*.
16. Lorica much longer, oblong ellipsoid in outline, with stout spines all over; porus with fine teeth
(xvi) *Tr. superba* var. *oblonga*.
16. Lorica large, spines very long and stout (more than 10μ) porus toothed (xvii) *Tr. megalacantha*.
17. Lorica ellipsoidal, narrowing at both ends, with a distinct neck bearing spines; one occasionally two rows of few spines below neck; posterior end terminated in a single spine surrounded by one row of similar ones
(xxv) *Tr. hystrix* var. *paucispinosa*.
18. Spines at posterior end straight, porus without teeth
(xix) *Tr. dangeardina* var. *glabra*.
18. Spines at posterior end curved (sometimes reduced), porus toothed (xviii) *Tr. armata*.
- (i) ***Trachelomonas volvocina* Ehr. var. *minuta* Fritsch (Fig. 6h).**

Envelope perfectly spherical, smooth, $8-10\mu$ in diameter, varying in colour from colourless to clear yellowish-brown, or even opaque brown. Porus sometimes surrounded by a thickened ring. Flagellum 2-3 times body length. Chloroplasts two only, each with a pyrenoid.

Common in most stagnant waters in Malaya. Cosmopolitan.

The variety is distinguished only by its much smaller size and may be a nutritional form.

(ii) **Trachelomonas rugulosa** Stein (Fig. 6m).

Envelope spherical, or nearly so, with thick, irregular sculptured striations of the wall running transversely, dull yellow to reddish-brown in colour; $17-20\mu$ in diameter. Porus with a slight thickening, but without teeth. Flagellum twice body length.

Collected from fish-ponds, Malacca. Probably widespread in distribution, since reported from Europe, America and Africa.

(iii) **Trachelomonas curta** Da Cunha emend. Déflandre (Figs. 6b, d).

Lorica spheroidal, compressed in the longitudinal direction, so that it appears wider than long when viewed laterally, circular in cross-section, smooth, 13μ long $\times$ $15-16\mu$ wide. Porus sometimes with a thickened ring surrounding it. Flagellum twice body length.

Collected from the lake in the Botanic Gardens, Singapore, fish-ponds and padi swamps in Malacca, Seremban, and Port Dickson. Probably widespread in distribution.

Reported from Europe, S. America and Australia.

(iv) **Trachelomonas lismorensis** Playfair (Figs. 6o, p).

Envelope spheroidal, compressed in the longitudinal direction, wider than long when viewed laterally, circular in cross-section, hyaline to yellowish-brown, bearing 3-4 rows of a few short conical spines, running transversely round the envelope; $6-9\mu$ long $\times$ 13μ wide, spines $1-2\mu$ long, porus $2-2.5\mu$ in diameter. Flagellum about twice body length.

Collected from fish-ponds and padi swamps, Malacca, occasional.

Reported from Australia.

The Malayan forms are smaller than those from Australia, but they obviously belong under this species.

(v) **Trachelomonas oblonga** Lemmermann (Fig. 6a).

Envelope ellipsoidal, slightly elongated, smooth, yellowish to dark brown, rounded at both ends, 18μ long $\times$ 14μ wide; porus with or without a ring-shaped thickening. Flagellum about twice body length.

Fairly common in most bodies of standing water in Malaya. Widespread in distribution.

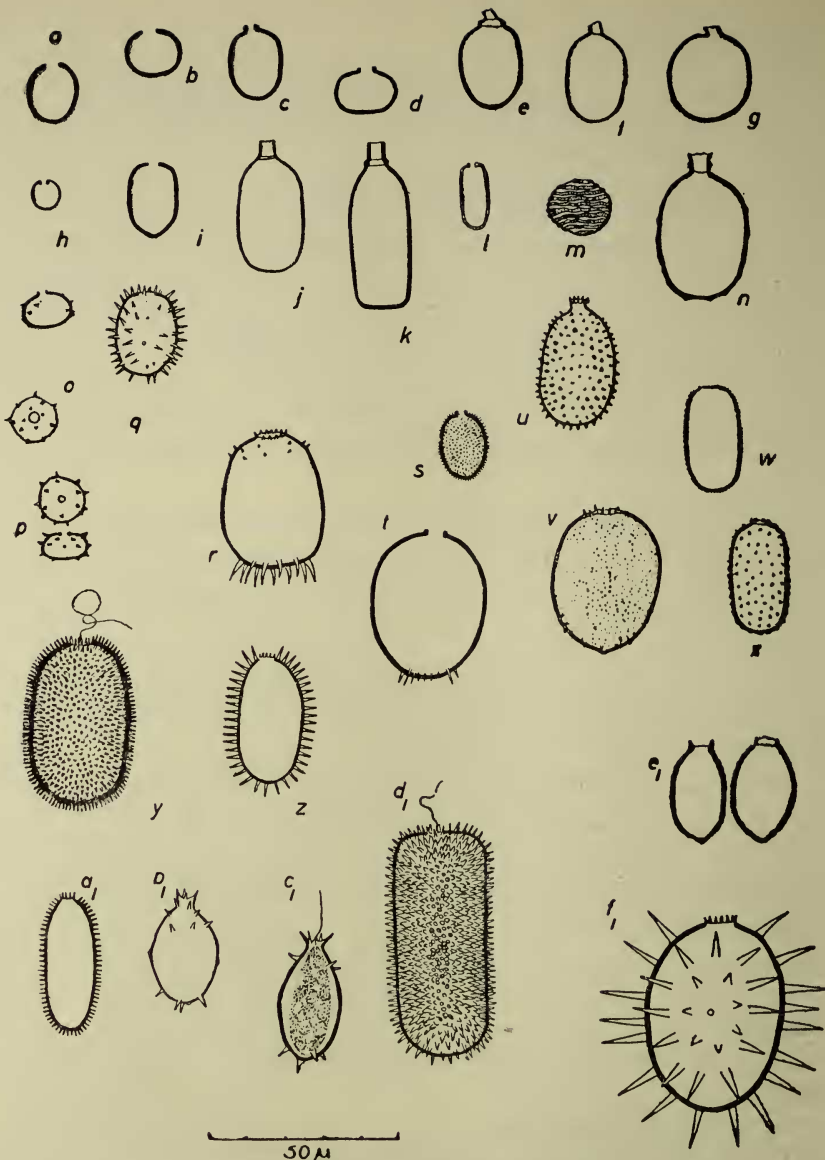


FIGURE 6

Malayan species of *Trachelomonas* Ehrenberg:—

a, *T. oblonga* Lemm.; b, d, *T. curta* Da Cunha emend. Défl.; c, *T. oblonga* var. *attenuata* Playf.; e-f, *T. similis* Stokes; g, *T. similis* var. *hyalina* Skv.; h, *T. volvocina* Ehr. var. *minuta* Fritsch; i, *T. conica* Playf.; j-k, *T. volzii* Lemm. var. *cylindracea* Playf.; l, *L. lacustris* Drez.; m, *L. rugulosa* Stein; n, *T. crebea* Kellicott; o-p, *T. lismorensis* Playf.; q, *T. superba* Swir.; r, v, *T. armata* (Ehr.) Stein; s, *T. hispida* (Perty) Stein; t, *T. dangeardiana* Défl. var. *glabra* (Playf.) Défl.; u, *T. mirabilis* Swir. var. *affinis* Skv.; w, x, *T. klebsii* Défl.; y, *T. allia* Drez.; z, *T. superba* Swir. var. *oblonga* Prowse; a₁, *T. hispida* (Perty) Stein var. *elongata* Prowse; b₁-c₁, *T. hystrix* Teiling var. *paucispinosa* Prowse; d₁, *T. zingeri* Roll; e₁, *T. scabra* Playf. var. *labiata* (Teiling) Hüber-Pest.; f₁, *T. megalacantha* Da Cunha.

(vi) **Trachelomonas oblonga** var. **attenuata** Playfair (Fig. 6c).

Differing from the type in being more cylindrical in shape, and slightly flattened at the anterior end. The porus may be thickened or may bear very fine teeth, 20μ long $\times$ 14μ wide. Less common than the type.

Reported from Europe, Australia and Africa.

Trachelomonas oblonga is a somewhat variable species, and it is not certain what justification there is to separate off so many varieties, as has been done. The above variety is the only one sufficiently distinct from the type, at least in the Malayan material, to warrant separation.

(vii) **Trachelomonas lacustris** Drez. (non **Tr. lacustris** Skv.) (Fig. 6l).

Envelope cylindrical, finely punctate, clear yellowish-brown in colour, broadly rounded at the posterior end, slightly flattened at the anterior end, $18-20\mu$ long $\times$ $8-9\mu$ wide. Porus without either teeth or a thickened ring. Flagellum about $1\frac{1}{2}$ times body length.

Collected from the lake in the Botanic Gardens, Singapore, and padi swamps, Malacca.

Reported from Europe, S. America and Australia.

The Malayan specimens are slightly smaller.

(viii) **Trachelomonas conica** Playfair (Fig. 6i).

Envelope cylindrical, smooth, clear yellowish-brown in colour, in the anterior half with the walls strictly parallel, but sloping conically at the posterior end, rounded at the apex of the cone, 20μ long $\times$ 14μ wide. Porus without either thickening or teeth. Flagellum about $1\frac{1}{2}$ body length.

Occasional in padi swamps, Malacca.

Reported from Australia and S. America.

(ix) **Trachelomonas hispida** (Perty) Stein emend. Défl. (Fig. 6s).

Envelope ellipsoidal, yellowish to reddish-brown, thickly covered with short, sharp, conical spines $14-25\mu$ long $\times$ $12-20\mu$ wide. Membrane sometimes finely punctate. Porus with or without a ring-like thickening. Flagellum $1\frac{1}{2}-2$ times body length.

Common in most standing waters in Malaya, on the whole smaller in size than reported elsewhere. Cosmopolitan in distribution.

(x) **Trachelomonas hispida** var. **elongata** Prowse var. nov. (Fig. 6a).

Differing from the type in being very much longer and narrower, more than twice as long as broad. Lorica elongate oblong, narrowing at both ends, and with the sides almost parallel in the middle

half, thickly set with short spines, porus surrounded by a ring of spines of the same length; 32μ long $\times$ 13μ wide without spines, 36μ long $\times$ 16μ wide with spines, porus 3.5μ wide.

A forma typica lorica valde longiore augustioreque, quam latitudo ipsa plus duplo longiore haec varietas differt. *Lorica* elongato-oblonga, utrinque paulatim angustata, spinis brevibus armata, in ore 3.5μ lato spinis aequialtis marginata, sine spinis 32μ longa, 13μ lata, cum spinis 36μ longa, 16μ lata.

Habitat: Malacca, in piscinis (Prowse 193 a).

(xi) **Trachelomonas allia** Drez. emend. Défl. (Fig. 6y).

Envelope cylindric-ellipsoidal, with broad, equally rounded ends, sides more or less parallel in the median half, reddish-brown in colour, thickly set with short, sharp, conical spines; $45\text{--}48\mu$ long $\times$ 30μ wide. Porus without thickening or teeth. Flagellum about body length.

Collected from padi swamps and fish-ponds, Malacca, occasional.

Reported from Europe, S. America and Indonesia.

(xii) **Trachelomonas klebsii** Déflandre (Figs. 6w, x).

Envelope distinctly cylindrical, with broadly rounded poles which may be slightly flattened, light brown in colour, thickly covered with short sharp conical spines; $25\text{--}30\mu$ long $\times$ $15\text{--}16\mu$ wide, porus $4\text{--}5\mu$ in diameter set with small teeth. Flagellum $1\frac{1}{2}$ times body length.

Collected from padi swamps, Malacca, occasional.

Reported from Europe, Venezuela, Java.

(xiii) **Trachelomonas zingeri** Roll (Fig. 6d₁).

Distinctly larger than the preceding. Envelope cylindrical, rounded posteriorly, often slightly flattened at the anterior end, $55\text{--}60\mu$ long $\times$ $23\text{--}25\mu$ wide, brownish in colour, and thickly set with medium-sized, sharp, conical spines. Porus sometimes with a thickened ring. Flagellum about $\frac{1}{2}$ body length.

Collected from padi swamps and one fish-pond, Malacca.

Reported from Russia.

Superficially the Malayan specimens look like *Tr. australica* (Playf.) Défl. var. *rectangularis* Défl. but the spines are distinctly conical and sharp-pointed. For that reason it seems better to include them under this species.

(xiv) **Trachelomonas mirabilis** Swir. var. *affinis* Skv. (Fig. 6u).

Envelope ellipsoidal, rounded at the posterior end, and bearing a cylindrical neck, distinctly toothed, at the anterior end; colour brown; the whole body of the envelope is thickly covered with

short, sharp, conical spines of uniform size; 37μ long $\times$ 20μ wide. Neck 4μ high $\times$ 4μ wide. Flagellum about body length.

Collected from padi swamps, Malacca.

Reported from Manchuria.

The type species, with the spines very much longer at both ends, has not been observed in Malaya so far, and the present variety shows very little variation in the Malayan material.

(xv) **Trachelomonas superba** Swir. emend. Déflandre (Fig. 6q).

Envelope ellipsoidal, broadly rounded at both ends, brown in colour, finely punctate with long, stout, sharp-pointed conical spines of uniform length evenly distributed over the surface; $27\text{--}35\mu$ long $\times$ $22\text{--}30\mu$ wide (with spines), spines $3\text{--}5\mu$ long. Porus without teeth. Flagellum about body length.

Common in most standing waters in Malaya. Cosmopolitan.

The Malayan specimens are slightly smaller than usual.

(xvi) **Trachelomonas superba** var. **oblonga** Prowse var. nov. (Fig. 6z).

Differing from the type in the much longer proportions, about twice as long as broad.

Envelope almost oblong in shape, rounded at both ends, densely covered with stout conical spines, and with a comparatively wide mouth bearing a ring of short teeth; dimensions 34μ long $\times$ 17μ wide without spines, 40μ long $\times$ 25μ wide with spines, spines $3\text{--}4\mu$ long, diameter of porus 4μ .

A forma typica dimensione longiore, quam latitudo ipsa fere duplo longiore haec varietas sat distincta.

Lorica ambitu oblonga vel fere, utrinque rotundata, spinis conoideis, rigidis $3\text{--}4\mu$ longis dense vestita, cum ore pro rata lato, 4μ in diam., secus marginem breviter dentato; sine spinis 34μ longa, 17μ lata, cum spinis 40μ longa, 25μ lata.

Habitat: Malacca, in locis oryza libus paludosis (Prowse 241a).

(xvii) **Trachelomonas megalacantha** Da Cunha (Fig. 6f₁).

Envelope large, oval, rounded at both poles, dark brown in colour, bearing very long, stout, conical spines, evenly distributed over the surface; 66μ long $\times$ 60μ wide (with spines), spines, 12μ long. Porus bearing fine teeth. Flagellum body length.

Collected from a padi swamp, Malacca.

Reported from Brazil.

The extremely large spines make this an unmistakable species.

(xviii) **Trachelomonas armata** (Ehr.) Stein (Figs. 6r, v).

Envelope ellipsoidal to ovoid, sometimes slightly wider at the posterior end, yellowish brown in colour, bearing long sharp,

curved spines at the posterior end, and much shorter straight ones at the anterior end; the length of the spines is variable, and in some forms is very much reduced; $33\text{--}40\mu$ long $\times$ $26\text{--}28\mu$ wide. Porus always toothed. Flagellum about twice body length.

Collected from fish-ponds and padi swamps in various localities in Malaya. Cosmopolitan in distribution.

This is a decidedly variable species, and numerous forms have been described. In the Malayan material there is so much gradation between the various forms, differing in length of spines and in shape, that there seems little justification in retaining the varietal names.

(xix) **Trachelomonas dangeardiana** Défl. var. **glabra** (Playf.) Défl. (Fig. 6t).

Envelope ellipsoidal, rarely ovoid, yellowish-brown in colour, bearing at the posterior end strong, sharp, conical spines, always straight and diverging from each other; the remainder of the lorica is perfectly smooth, and the porus is without teeth, although there may sometimes be a ring-shaped thickening; 40μ long $\times$ 30μ wide, spines $5\text{--}6\mu$ long. Flagellum about twice body length.

Collected from padi swamps, Malacca.

Reported from Australia and Venezuela.

The variety *glabra* differs from the type in the complete absence of spines from the anterior half, and is the only variety yet observed in Malaya, the type not having turned up so far.

Trachelomonas dangeardiana and its varieties can always be distinguished from *Tr. armata* (E.) Stein by the straight posterior spines, and the absence of teeth from the porus.

(xx) **Trachelomonas scabra** Playf. var. **labiata** (Teiling) Hübert-Pestalozzi (Fig. 6e, 1).

Envelope ovoid, slightly narrowed at both ends, slightly compressed dorsiventrally, brown in colour, with a very rough surface; 28μ long $\times$ 17μ wide. Neck divided into two very distinct lobes. Flagellum twice body length.

Collected from padi swamp in Malacca.

Reported from Sweden.

This variety is unmistakable in its bilabiate condition.

(xxi) **Trachelomonas crebea** Kellicott emend. Défl. (Fig. 6m).

Envelope regularly ellipsoidal, irregularly punctate and decidedly rough, golden to reddish-brown in colour; porus with a widish cylindrical neck, irregularly toothed; $39\text{--}40\mu$ long $\times$ 25μ wide, neck 5μ long $\times$ 6μ wide. Flagellum about body length.

Collected from a padi swamp, Malacca.

Reported from Europe, N. America, S. America.

The Malayan specimens are distinctly larger in size.

(xxii) **Trachelomonas volzii** Lemm. var. **cylindracea** Playf. (Figs. 6j, k).

Envelope distinctly cylindrical, sides parallel, rounded or almost straight at the posterior end, conical at the anterior end, bearing a straight cylindrical neck thickened at the base, completely smooth, brown in colour; the whole is shaped like a bottle; $32-42\mu$ long $\times$ $16-17\mu$ wide, neck $5-7\mu$ long $\times$ 4μ wide. Flagellum about body length.

Collected from fish-ponds, padi swamps, drains, Malacca, Seremban, Singapore, Port Dickson.

Reported from Australia.

The characteristic bottle shape makes this variety very easy to recognise.

(xxiii) **Trachelomonas similis** Stokes (Figs. 6e, f).

Envelope ellipsoidal, yellowish-brown in colour, regularly punctate, rounded at both ends and bearing at the anterior end a curved, inclined neck, often slightly swollen at the base, lightly toothed; 27μ long $\times$ 16μ wide, neck 5μ long. Flagellum about body length.

Collected from the lake in the Botanic Gardens, Singapore, and from fish-ponds and padi swamps, Malacca, common.

Reported from Europe, America, Asia and Java.

(xxiv) **Tr. similis** var. **hyalina** Skvortzow (Fig. 6g).

Differing from the type in being nearly spherical, and perfectly smooth without punctae; 25μ long $\times$ 22.5μ wide, neck $3-4\mu$ long. Flagellum about body length.

Collected from the lake in the Botanic Gardens, Singapore, and from padi swamps, Malacca.

Reported from Burma.

Skvortzow describes this as being hyaline, brown, but the Malayan specimens range from completely colourless to opaque brown. On the other hand the envelope is entirely without punctae, and the edge of the neck always quite smooth.

(xxv) **Trachelomonas hystrix** Teiling var. **paucispinosa** Prowse var. **nov.** (Figs. 6b₁, c₁).

Differs from the type in the considerable reduction of the number of spines, particularly in the median part of the envelope.

Envelope yellowish, ellipsoidal, narrowing equally at both ends; neck short, wide, ornamented by a ring of 5-6 stout spines, and

about a fifth of the way behind the neck bearing another ring of stout conical spines, while at the posterior end there is a single stout spine surrounded by a ring of 3–4 others, the tail spine usually being longer; occasionally 1–2 very short almost wart-like spines are borne in the median region; 33μ long $\times$ 16μ wide, neck $4\text{--}5\mu$ wide $\times$ $2\text{--}3\mu$ high. Flagellum about half body length. Chloroplasts parietal, discoid, 4μ in diameter.

A forma typica haec varietas spinis perpaucissimis praecipue in loricae medio differt.

Lorica luteola, ellipsoidea, anteriore abrupte constricta, in ore 5–6 spines, rigidis ornata, infra orem spinis consimilibus in unam seriem dispositis, prope basin 3–4 spinis similiter dispositis, et imo posteriore spina unica armata, in altera parte inermis vel interdum medio 1–2 spinis brevissimis vel verrucoideus praedita, protoplastum fere complexa, 33μ longa, 16μ lata, in ore $4\text{--}5\mu$ lata, $2\text{--}3\mu$ alta. *Flagellum* dimidio longum. *Chlorophora* parietalia, discoidea, 4μ in diam.

Habitat: Malacca in locis oryzalibus paludosis et stagnis piscatoriis (Prowse 186a).

Strombomonas Déflandre 1930

(*Trachelomonas* Ehrenberg pro parte)

Separated off from *Trachelomonas* on the basis that there is no porus, as in that genus, and the neck is wider, and generally longer, tapering gradually into the body of the lorica, and not set off sharply. The wall is often variable in thickness, but is very rarely punctate, and rarely ornamented by scrobiculations, perforations or spines. The stigma is large, and the flagellum relatively shorter than in *Trachelomonas*, rarely exceeding body length. There is also a much greater tendency for the protoplast to occupy the whole envelope.

Key to the species

1. Lorica nearly spherical in outline, with short neck and a sharp pointed tail (ii) *Str. praeliariis* var. *brevicollaris*.
1. Lorica oval, sides nearly parallel, neck short and wide, tail short and blunt (iii) *Str. deflandrei*.
1. Lorica fusiform 2.
1. Lorica almost cylindrical, sides straight or slightly concave, and slightly narrower at the posterior end. Outline hexagonal. Shortish neck and sharp tail . . . (i) *Str. girardiana*.

1. Lorica rhombic in outline 3.
2. Lorica long, fusiform, relatively narrow, neck toothed
(iv) *Str. australica*.
2. Lorica relatively short. Neck short, not toothed
(v) *Str. fluviatilis*.
3. Lorica smaller, 30μ long, tapering rather sharply to neck and tail (vi) *Str. schaunslundii*.
3. Lorica larger, 70μ or over, tapering less sharply and more conically to the tail (vii) *Str. gibberosa*.

(i) **Strombomonas girardiana** (Playf.) Défl. (Fig. 5l).

Envelope yellowish, rough, circular in cross-section, almost hexagonal in outline, with sides straight or slightly concave, or narrowing slightly in the posterior direction, sloping abruptly at the posterior end to the sharp, conical, tail, and similarly at the anterior end to the cylindrical neck; sometimes extra thickenings on the wall increase the angular appearance of the outline; 40μ long $\times$ 23μ wide, neck 6μ long $\times$ 6μ wide, tail 11μ long. Flagellum about body length.

Collected from padi swamps and fish-ponds, Malacca, occasional.

Reported from Australia, Egypt and Venezuela.

(ii) **Strombomonas praeliariis** (Palmer) Défl. var. **brevicollaris** Prowse var. nov. (Fig. 5k).

Differing from the type by its very short neck.

Envelope hyaline to pale yellow, nearly spherical, coarsely roughened, and tapering sharply to a tail posteriorly; bearing a low wide neck at the anterior end; 32μ long (including neck and tail) $\times$ 24μ wide; neck 7.5μ wide $\times$ 2μ high; tail 7.5μ long. Flagellum about body length. Protoplast filling most of the envelope. Chloroplasts parietal, discoid, $3-4.5\mu$ in diameter.

A forma typica haec varietas ore breviori haud constricto differt.

Lorica hyalina vel lutescens, globosa, asperissima, apice collo 7.5μ lato, 2μ alto praedita, basi in caudum 7.5μ longam abrupte producta, cum cauda colloque 32μ longa, 24μ lata. *Flagellum* loricae aequilongum vel. fere. *Chlorophora* parietalia, discoidea, $3-4.5\mu$ in diam.

Habitat: Malacca in locis oryzalibus paludosis (Prowse 240 a).

(iii) **Strombomonas deflandrei** (Roll) Défl. (Fig. 5r).

Envelope brown, rough, circular in cross-section, broadly oval in outline with the sides sometimes nearly parallel, rounded at the poles, bearing a short, conical, blunt or pointed tail at the poste-

rior end, and a short, wide neck, often obliquely cut, at the anterior end; 33μ long $\times$ 22μ wide, neck 3μ high $\times$ 8μ wide. Flagellum about $1\frac{1}{2}$ body length.

Collected from padi swamps and fish-ponds, Malacca, occasional.

Reported from Russia.

(iv) **Strombomonas australica** (Playf.) Défl. (Figs. 5m–p).

Envelope hyaline to clear yellow, rough to almost smooth, circular in cross-section, elongate fusiform in outline, tapering to a long, sharp tail-piece (occasionally short and blunt) at the posterior end, and terminating in a long cylindrical neck, usually toothed, at the anterior end; $40\text{--}66\mu$ long $\times$ $17\text{--}20\mu$ wide, neck $8\text{--}12\mu$ long $\times$ $3\text{--}5\mu$ wide, tail $8\text{--}13\mu$ long. Flagellum about $1\frac{1}{2}$ body length.

Collected from fish-ponds and padi swamps, Malacca.

Reported from Australia and China.

The Malayan specimens showed a wide degree of variation, some forms coming near to forms of the succeeding species, *Str. fluviatilis* (Lemm.) Défl.

(v) **Strombomonas fluviatilis** (Lemm.) Défl. (Fig. 5q).

Envelope hyaline to clear brown, rough, circular in cross-section, ellipsoidal-fusiform in outline, narrowing posteriorly to a short sharp tail, and anteriorly to a comparatively short, straight neck, not toothed; $27\text{--}28\mu$ long $\times$ $12\text{--}13\mu$ wide, neck 3μ long $\times$ 3μ wide, tail 3μ long. Flagellum about body length.

Collected from fish-ponds and padi swamps, Malacca.

Reported from Europe, Asia, S. America and Java.

This may be distinguished from shorter forms of the preceding species by its smaller size, and distinctly shorter neck and tail.

(vi) **Strombomonas schauinslandii** (Lemm.) Défl. (Fig. 5h).

Envelope hyaline to yellowish-brown, rough, circular in cross-section, broadly rounded and slightly rhombic in the median part, tapering fairly sharply to a pointed tail at the posterior end, and bearing a relatively long, smooth, cylindrical neck, widening slightly at the opening, but not toothed, at the anterior end; 32μ long $\times$ 22μ wide, neck 12μ long $\times$ 6μ wide, tail 11μ long. Flagellum about body length.

Collected from fish-ponds and padi swamps, Malacca.

Reported from Siam, Venezuela, Manchuria, Australia and Java.

This may be distinguished from the next species by its smaller size, less rhombic outline, relatively longer neck, and the sharpness with which it tapers into the tail-piece.

(vii) ***Strombomonas gibberosa*** (Playf.) Défl. (Figs. i, j).

Envelope hyaline to light brown, smooth or rough, circular in cross-section, distinctly broadly rhombic in outline, tapering to a sharp tail posteriorly, and to a wide neck at the anterior end; larger than the preceding, $70-75\mu$ long $\times$ $33-36\mu$ wide, neck $12-16\mu$ long $\times$ $7-8\mu$ wide. Flagellum about body length.

Collected from fish-ponds, padi swamps, drains, Malacca.

Reported from Europe, Manchuria, Australia and Venezuela.

This and the previous species are evidently related, and should intermediate forms turn up, it may be necessary to combine the two species.

Colourless Eugleninae

Cells completely devoid of chloroplasts, but possessing a definite cytostome and reservoir, and storing paramylum.

Key to the families

A. Possessing a stigma. Cells elongate fusiform, almost needle shaped *Cyclidiopsidaceae*.

B. Completely without a stigma.

I. Cells without the special rod-shaped bodies or siphon ("staborgan") near the reservoir; more frequently rounded in cross-section, usually free-swimming, with 1-2 flagella, metabolic or not

Astasiaceae.

II. Cells bearing a specialised rod-shaped body or siphon near the cytostome and reservoir. Generally showing dorsiventral organisation, frequently crawling, sometimes swimming, with 1-2 flagella, metabolic or non-metabolic, often holozoic in nutrition

Peranemaceae.

Cyclidiopsidaceae

Cells colourless, completely without plastids, very long fusiform or needle shaped, rigid and not metabolic. Cytostome centrally placed at the anterior end, well-marked, leading to an elongate ellipsoidal reservoir. Stigma distinct, next to the reservoir. Nucleus central, cylindrical to elongate oval. Paramylum long rods or needles.

One genus only *Cyclidiopsis* Korschikow.

Cyclidiopsis Korschikow 1917

Characters of the family.

One species recorded for Malaya *Cycl. acus*.

Cyclidiopsis acus Korschikow (Fig. 7a).

Cell very long, fusiform to needle shaped, rigid, tapering posteriorly to a long thin tail-piece, truncate at the anterior end, with a centrally placed cytostome leading to a long oval reservoir; 125μ long $\times$ 5μ wide. Flagellum short, less than $\frac{1}{4}$ body length. Periplast apparently smooth. Eye-spot oval, crimson, next to the reservoir, distinct. Cytoplasm hyaline, with 5–8 long thin cylindrical paramylum granules. Nucleus central, long cylindrical.

Collected from the Malacca river in a plankton net haul, and once from a padi swamp.

Reported from Russia, Sweden, Germany and Australia.

There is a good deal of confusion about this species, and many authors would include it under *Euglena acus* as a colourless form. Hyaline forms of the latter have occurred in Malayan collections, and I have been fortunate to be able to compare the two. The forms of *Euglena acus* differ from the type only in the absence of the chloroplasts. The cytostome is slightly one-sided, and the nucleus is shorter and rounder than in *Cyclidiopsis*, while the reservoir of the latter is much more prominent. No pigmented forms of *Euglena acus* having quite the same characteristics as *Cyclidiopsis acus* have occurred in the Malayan material, so for the time being it seems better to retain the separate generic name. Further research may of course reveal that such a separation is not justified.

Astasiaceae

Cells solitary, free-swimming, metabolic or rigid, fusiform, cylindrical, ovoid or ellipsoidal, completely without chloroplasts; stigma absent (except in *Khawkinia* Jahn & McKibben, which has not been reported from Malaya); flagella 1–2. Vacuolar system a typical cytostome and reservoir without any rod-shaped or tubular siphon. Storage material paramylum and sometimes fat. Nutrition generally saprophytic, occasionally holozoic.

Key to the genera

1. Cell with one flagellum 2.
1. Cell with two unequal flagella, distinctly metabolic *Distigma*.
2. Cell distinctly metabolic, oval to fusiform, roundish in cross-section *Astasia*.
2. Cell more rigid, distinctly curved to one side .. *Menoidium*.

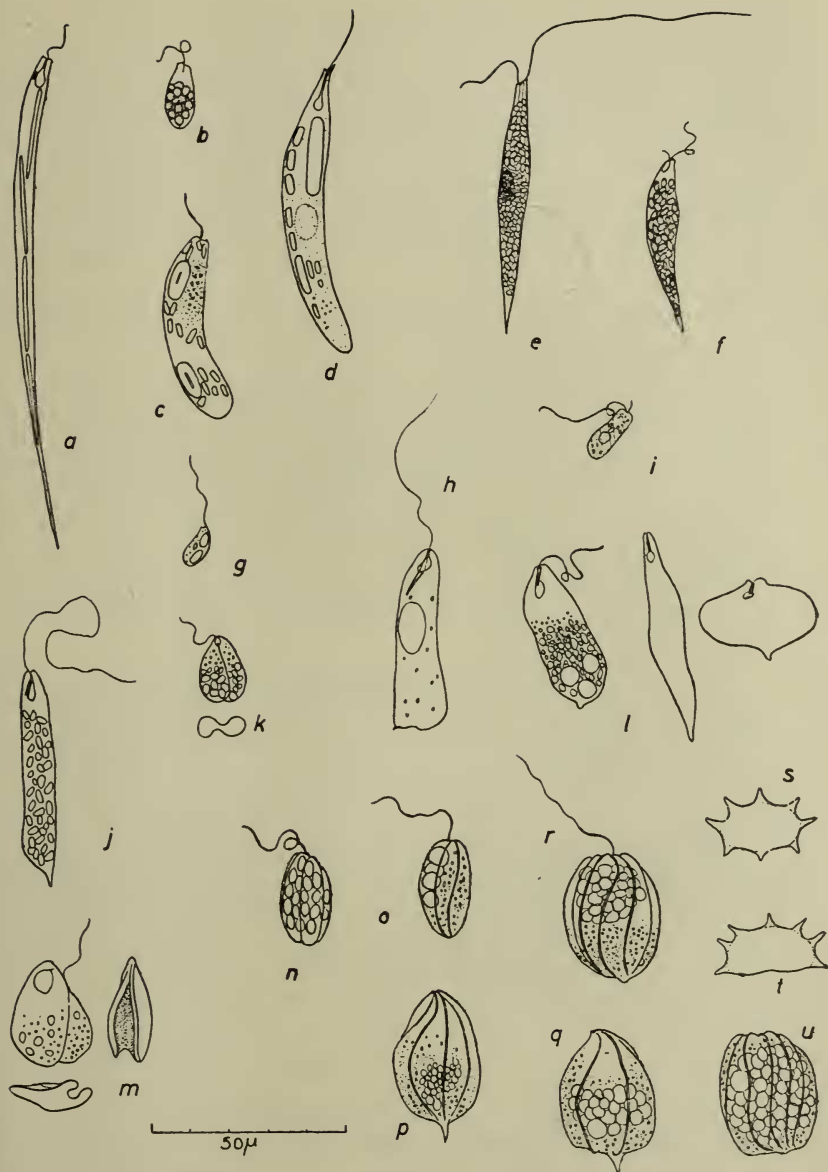


FIGURE 7

Colourless Eugleninae in Malaya:—

a, *Cyclidiopsis acus* Korschikow; b, *Astasia variabilis* Skv.; c, *Menoidium obtusum* E.G. Pringsheim; d, *Menoidium pellucidum* Perty; e-f, *Distigma proteus* Ehr.; g, *Menoidium obtusum* E.G. Pringsheim, very small form; h, *Peranema cuneatum* Playf.; i, *Distigma curvatum* E.G. Pringsheim; j, *Peranema curvicauda* Skuja; k, *Petalomonas mediocanellata* Stein; l, *Peranema kupfferi* Skuja; m, *Petalomonas asymmetrica* Shawhan & Jahn; n-o, *Petalomonas abscissa* (Duj.) Stein var. *pellucida* Skuja; p-q, *Petalomonas platyrrhyncha* Skuja; r-u, *Petalomonas heptaptera* Prowse.

Astasia Dujardin 1841

Cell distinctly metabolic, changing shape quite rapidly, but usually cylindrical or fusiform when swimming. Eye-spot absent. Flagellum 1, forking typically where it enters the reservoir. Vacuolar system as in *Euglena* with a typical cytostome and reservoir. Paramylum granules generally round or ovoid. The species of this genus come very close to being colourless forms of *Euglena*, and further research may result in the transfer of many of them to that genus.

One species reported for Malaya *As. variabilis*.

Astasia variabilis Skvortzow (Fig. 7b).

Cell small, oval, rounded at the posterior end, rounded or slightly truncate at the anterior end, but drawn out a little at the anterior end when swimming; distinctly metabolic when not swimming; 18–20 μ long $\times$ 7 μ wide. Flagellum about body length. Periplast apparently smooth. Cytoplasm clear, containing 10–15 oval paramylum granules.

Collected from a drainage channel in Malacca, occasional, but more frequent in putrefaction cultures from the same source.

Reported from China.

I have tentatively placed the Malayan specimens under this species, since they seem to agree most closely with Skvortzow's description, although the latter is lacking in one or two details.

Menoidium Perty 1852

Cells single, free-swimming, rigid or hardly metabolic, more or less flattened dorsiventrally, and distinctly curved to one side laterally, rounded or slightly pointed at the posterior end, truncate or oblique at the anterior end. Flagellum 1, typical for *Euglena*. Periplast longitudinally striate. Paramylum granules rod or ring-shaped, often with 1–2 large ones.

Key to the species

1. Cell narrowed to a neck at the anterior end, with two pointed lip-like projections, slightly narrowed but rounded at the posterior end (i) *M. pellucidum*.
 1. Cell only very slightly narrowed at the anterior end, truncate, broadly rounded at the posterior end .. (ii) *M. obtusum*.
- (i) **Menoidium pellucidum** Perty (Fig. 7d).

Cell very flat, distinctly curved to one side, convex side more curved than the concave side, narrowed to a neck-like end, often

terminating obliquely in two pointed lips; at the posterior end slightly narrowed but rounded; $70-80\mu$ long $\times$ $10-12\mu$ wide. Flagellum up to about $\frac{1}{2}$ body length. Periplast longitudinally striate, but these are not always visible. Cytoplasm faintly granular to hyaline, containing 1-2 large cylinders and several small rod-shaped paramylum granules.

Collected from fish-ponds, Malacca. Widespread in distribution.

(ii) **Menoidium obtusum** E. G. Pringsheim (Figs. 7b, g).

Cell only somewhat flattened, curved to one side, broadly rounded at the posterior end, very slightly narrowed at the anterior end, rather truncate, without any pointed lips; $40-45\mu$ long $\times$ 10μ wide. Flagellum about $\frac{1}{2}$ body length. Cytoplasm slightly granular to hyaline; paramylum two large rings and several smaller scattered rods. Striation of the periplast not visible.

Collected from fish-ponds, Malacca.

Reported from Central Europe and Brazil.

The very small form shown in fig. 7g, 10μ long $\times$ 5μ wide, is so obviously related to this species that it is probably only a juvenile form. I have therefore included it here.

Distigma Ehrenberg 1838

Cell usually distinctly metabolic, with two flagella, a long swimming flagellum and a shorter trailing one. Periplast spirally striate. Vacuolar system similar to that in *Astasia* without any rod-shaped bodies or siphon, although some specimens show a superficial resemblance to species of *Peranema*. Paramylum usually medium to small oval granules, often densely packed.

Key to the species

1. Cell, long, fusiform, tapering almost to a point at the posterior end, narrowed at the anterior end, with a distinct notch $48-65\mu$ long $\times$ $8-10\mu$ wide (i) *D. proteus*.
1. Cell smaller, shorter, varying from cylindrical to pear-shaped, rounded anteriorly, slightly narrower, or broadly rounded at the posterior end, metabolic. $12-16\mu$ long $\times$ 8μ wide
(ii) *D. curvatum* f. *minor*.

(i) **Distigma proteus** Ehrenberg em. Pringsheim (Figs. 7e, f).

Cell elongate-fusiform, tapering almost to a point at the posterior end, broadest nearer the anterior end, but tapering towards the cytostome, where there is a distinct notch; $48-65\mu$ long $\times$

8–10 μ wide. Longer flagellum about body length, shorter flagellum about $\frac{1}{4}$ body length. Distinctly metabolic, even when swimming. Periplast spirally striate, but the cell contents are often so dense as to render the striations practically invisible. Paramylum abundant small oval rods or cylinders, nearly filling the cell.

Collected from padi swamps, Malacca. Widespread in distribution.

(ii) **Distigma curvatum** E. G. Pringsheim fa. **minor** Pringsheim (Fig. 7i).

Cell almost cylindrical to pear-shaped, rounded anteriorly, rounded or slightly narrowed at the posterior end, more or less slightly curved, very metabolic; 12–16 μ long $\times$ 8 μ wide. Long flagellum about 1–1 $\frac{1}{2}$ body length, shorter flagellum $\frac{1}{2}$ body length or less. Periplast finely, spirally striate. Paramylum ranging from large rod-shaped granules to small oval granules.

Collected from padi swamps, Malacca.

Reported from Czechoslovakia.

The Malayan specimens show minor differences from the type, being more usually nearly cylindrical. It seems best however, to include them under this species.

Peranemaceae

Cells metabolic or rigid, often crawling but also free-swimming, usually bilaterally asymmetrical, and dorsiventrally organised. Flagella 1–2. Vacuolar system as in *Euglena*, but usually with two rod-shaped, or a tubular, siphon, the former closely associated with the reservoir, while the latter may reach the full length of the cell. In some cases the siphon can be extruded at the anterior end. Storage material paramylum granules, and sometimes fat. The cells are completely without stigma and chloroplast, but occasionally partly digested spheres of chloroplast material may be seen inside the cell, giving the superficial appearance of chloroplasts. Nutrition usually holozoic.

Key to the genera

1. Cell with 1 flagellum 2.
1. Cell with 2 flagella 3.
2. Cell distinctly metabolic with rod-shaped siphon organs in the reservoir *Peranema*.
2. Cell rigid, periplast firm, generally somewhat flattened
Petalomonas.

3. Cell not flattened, usually somewhat metabolic *Heteronema*.
3. Cell distinctly flattened 4.
4. Swimming flagellum projecting forwards, much longer than trailing flagellum *Notosolenus*.
4. Swimming flagellum hardly as long as, or much shorter than the trailing flagellum. Siphon a long tube reaching nearly the full length of the cell *Entosiphon*.

Peranema Dujardin 1841

Cell very metabolic, with soft periplast. Flagella 1 or occasionally 2. Cytostome and reservoir as in *Euglena* but a distinct pair of rod-shaped bodies can be seen against the reservoir. Storage products paramylum granules, usually round or oval, and often fat. In many species nutrition distinctly holozoic.

Key to the species

1. Cell elongate wedge-shaped, narrowing towards the anterior, broadly rounded at the posterior end, with a short, sharp, laterally-placed tail-piece (i) *P. cuneatum*.
1. Cell fusiform, tapering posteriorly to a sharp tail, narrowing slightly towards the anterior end (ii) *P. kupfferi*.
1. Cell elongate, to almost elongate-cylindrical, slightly narrowed at the anterior end, bearing at the posterior end a one-sided, curved, sharp-pointed tail (iii) *P. curvicauda*.

(i) *Peranema cuneatum* Playf. (Fig. 7h).

Cell elongate wedge-shaped, narrowing slightly towards the anterior end, broadly rounded at the posterior end, with a short, sharp, pointed tail-piece lying to one side; very metabolic; 66–70 μ long $\times$ 15–20 μ wide. Flagellum about body length. Cytoplasm practically hyaline, with a few small scattered granules of paramylum. The rod-shaped siphon bodies prominent below the reservoir. Periplast apparently smooth.

Collected from a fish-pond at Alor Gajah, Malacca, not common.

Reported from Australia.

Playfair's description is incomplete, but the shape of the organism is so characteristic that it seems certain that the Malayan specimens belong here.

(ii) *Peranema kupfferi* Skuja (Fig. 7l).

Cell fusiform, narrowing at both ends, posteriorly tapering to a pointed tail, very metabolic, 80 μ long $\times$ 14 μ wide extended, 45 μ

long $\times$ 33μ wide contracted. Flagellum about body length. Periplast distinctly spirally striate. Cytoplasm granular, with numerous round to oval paramylum granules of varying size almost filling the cell. Rod-shaped siphon bodies reaching the full length of the cytostome.

Collected from padi swamps, Malacca, fairly common.

Reported from Sweden.

The Malayan specimens are only half the size of the type, but agree in nearly every other way, particularly as to shape and movement. Separation on the basis of size alone is a very dubious practice, especially as we know so little about the nutrition and growth of these organisms. For that reason the Malayan specimens have not been given a varietal name.

(iii) **Peranema curvicauda** Skuja (Fig. 7j).

Cell elongate, lanceolate to almost cylindrical, narrowed slightly at the anterior end, tapering to a sharp-pointed tail-piece, set to one side at the posterior end, tail-piece distinctly curved; $50-54\mu$ long $\times$ $8-10\mu$ wide. Cell very metabolic. Flagellum about body length or longer. Reservoir long, oval-shaped with well marked rod-shaped siphon bodies. Periplast firm, longitudinally striate, but the striations often faint. Cytoplasm clear, containing a number of loosely arranged oval paramylum granules.

Collected from padi swamps, Malacca, occasional.

Reported from Sweden.

Petalomonas Stein 1859

Cell ovoid, fusiform, oval or triangular, with a firm periplast, often ribbed; dorsiventrally flattened. Cytostome groove usually asymmetrical at the anterior end. Flagellum one, thick, spiralling at the distal end in swimming. Rod-shaped siphon bodies often difficult to see, although present. Nucleus central, relatively large. Cell only very slightly metabolic. Nutrition saprophytic to holozoic.

Key to the species

1. Periplast without ribs 2.
1. Periplast with ribs 3.
2. A median longitudinal furrow present on both the dorsal and ventral face (i) *P. mediocanellata*.
2. A furrow present at one side, not median
(ii) *P. asymmetrica*.
3. Dorsal face with two longitudinal ribs, ventral face without.
Cell oval in outline (iii) *P. abscissa* var. *pellucida*.

3. Cell with 3 well-marked ribs on the dorsal face, the ventral side slightly concave. Bearing a short sharp tail at the posterior end (iv) *P. platyrrhynca*.

3. Cell with 5 well marked ribs on the dorsal face, and 2 on the ventral face, with sometimes a median one as well. Posterior end bearing a short wart-like outgrowth

(v) *P. heptaptera*.

(i) ***Petalomonas mediocanellata*** Stein (Fig. 7k).

Cell ovoid, flattened, rounded at the posterior end, narrowed and rounded at the anterior end, bearing a median longitudinal furrow on both the dorsal and ventral faces $18-20\mu$ long $\times$ $13-15\mu$ wide. Flagellum about body length. Cytoplasm slightly granular, with many medium sized round paramylum granules crowded in the posterior half.

Collected from fish-ponds, Malacca.

Reported from Sweden and U.S.A.

The Malayan specimens are slightly smaller.

(ii) ***Petalomonas asymmetrica*** Shawhan and Jahn (Fig. 7m).

Cell ovoid, flattened, broadly rounded at the posterior end, narrowing at the anterior end; on the left side (viewed from the dorsal face) there is a deep furrow, with the dorsal edge projecting further over than the ventral, the furrow curving slightly towards the hollowed ventral surface; $27-30\mu$ long $\times$ $22-25\mu$ wide, 8μ thick. Flagellum about body length. Cytoplasm clear at the anterior end, slightly granular in the posterior half, containing scattered round granules of paramylum.

Collected from fish-ponds, Malacca.

Reported from U.S.A.

(iii) ***Petalomonas abcisca*** (Duj.) Stein var. ***pellucida*** Skuja (Figs. 7n, o).

Cell oval, with sides sometimes nearly parallel, flattened, slightly narrowed at the anterior end, broadly rounded to almost truncate at the posterior end, dorsal surface slightly convex, ventral surface concave; two prominent ribs run longitudinally the full length of the dorsal surface; 25μ long $\times$ 14μ wide. Flagellum $1-1\frac{1}{2}$ body length. Periplast firm, colourless smooth. Cytoplasm clear to very slightly granular, containing several scattered, oval, paramylum granules.

Collected from padi swamps, Malacca.

Reported from Sweden.

The slightly larger size of the Malayan specimens is of unimportance taxonomically with such small organisms.

(iv) **Petalomonas platyrrhyncha** Skuja (Figs. 7p, q).

Cell oval, flattened, broadly rounded to truncate at the posterior end, with a sharp tail piece, narrowing anteriorly; $39\text{--}40\mu$ long $\times$ $22\text{--}25\mu$ wide; there are three prominent longitudinal ribs on the dorsal face, which is slightly convex, the ribs converging at the ends; ventral face hollowed. Flagellum about $\frac{1}{2}$ body length. Periplast firm, smooth. Cytoplasm clear, or slightly granular, with several medium sized round paramylum granules.

Collected from fish-ponds, Malacca.

Reported from Sweden.

(v) **Petalomonas heptaptera** Prowse sp. nov. (Figs. 7r–u).

Allied to *P. platyrrhyncha* Skuja, but broader and with seven ridges instead of five.

Cell broadly oval to almost rectangular in outline, bearing a short blunt wart-like tail posteriorly, broadly rounded at the anterior end, dorsi-ventrally flattened, 30μ long $\times$ 25μ wide, $15\text{--}18\mu$ thick. On the dorsal surface bearing five prominent wing-like ridges, and with two such ridges on the ventral surface, with sometimes a third central one, the whole spiralling to the left. Flagellum about $1\frac{1}{2}$ body length. Cytoplasm slightly granular. Paramylum densely packed, medium-sized granules.

A *P. platyrrhyncha* Skuja, cui affinissima, carinis 7 (non 5) latioribus differt.

Cellula ambitu late ovata vel fere rectangularis, posteriore cum cauda verrucosa obtusa, anteriore late rotundata, utrinque complanata, 30μ longa, 24μ lata, $15\text{--}18\mu$ crassa, dorso 5-alata, ventre 2-, rarissima 3-alata, omnibus alis in laevum spiraliter tortis. *Flagellum* sesquialtum. *Cytoplasma* parce granulosum. *Paramylum* dimensione mediocre cum granulis globosis dense dispositis.

Habitat: Malacca, in piscinis (Prowse 227 a).

Heteronema Dujardin 1841 emend. Stein 1878

Cells fusiform to nearly cylindrical, not flattened, but nearly circular in cross-section, very metabolic. Flagella 2, the longer projecting forward, the shorter one trailing. Reservoir usually well marked, with the rod-shaped siphon bodies extending along the side. Saprophytic to holozoic in nutrition.

Key to the species

1. Cell long and slender, ending in a sharp point at the posterior end (i) *H. leptosomum*.
1. Cell almost cylindrical (when swimming) to slightly fusiform, slightly narrowed but rounded at both ends
(ii) *H. polymorphum*.

1. Cell almost cylindrical, narrowed slightly and truncate at each end (when swimming) with a distinct invagination at the posterior end (iii) *H. invaginatum*.

(i) ***Heteronema leptosomum*** Skuja (Fig. 8c).

Cell long and slender, sometimes almost needle-shaped, slightly truncate at the anterior end, tapering to a point at the posterior end; $40-55\mu$ long $\times$ $3-7\mu$ wide. The long flagellum about $\frac{3}{4}$ body length, the shorter about $\frac{1}{4}$ body length. Periplast apparently smooth. Cytoplasm hyaline, with scattered grains of paramylum. In the swimming stage the cell is extended and long, and very thin, but in the metabolic stage a large bulge forms at the posterior end and rapidly progresses forwards.

Collected from padi swamps, Malacca.

Reported from Lithuania.

The very characteristic long slender shape of this species makes it unmistakable.

(ii) ***Heteronema polymorphum*** Defl. (Fig. 8b).

Cell cylindrical to slightly fusiform when swimming, slightly narrowed and rounded at both ends; $80-100\mu$ long $\times$ $10-20\mu$ wide, in the metabolic stage often quite short and broad. Long forward projecting flagellum nearly body length, shorter trailing flagellum, $1/3-1/2$ body length. Periplast apparently smooth. Cytoplasm packed with oval paramylum granules.

Collected from padi swamps, Malacca.

Reported from France.

(iii) ***Heteronema invaginatum*** Prowse nov. sp. (Fig. 8a)

The most characteristic feature of this species is the invagination of the posterior end, a feature found in no other species. Cell truncate fusiform in outline, round in section, narrowing slightly at the anterior end; posterior end markedly invaginate for about $\frac{1}{4}$ length of the cell, narrowing slightly when the cell is swimming, but opening out when the cell is stationary; cell $48-50\mu$ long $\times$ $8-9\mu$ wide. Cytostome and reservoir well marked at anterior end, reaching nearly $\frac{1}{4}$ way along cell. Storage products densely packed granules of paramylum. Longer flagellum pointed forward during swimming, about body length, shorter trailing, about $\frac{1}{4}$ body length.

Inter *Heteronema* spp. forma ambitu fusiformi utrinque truncata, transverse orbiculari, posteriore quarta parte invaginata, haec species sat distincta.

Cellula $48-50\mu$ longa, $8-9\mu$ lata, parum metabolica, ambitu truncato-fusiformis, transverse orbicularis; anteriorem versus paulo

angustata, cum cytostomate conspicuo quarta parte ex ejus apice attingenti; posteriore quarta parte invaginata, movente angustata, immovente dilatata. *Granula paramylonica* copiosa, dense cumulata. *Flagella* duo: longius cellulae aequilongum, motionis directionem indicans, alterum brevius priori circa aequilongum.

Habitat: Malacca in locis oryza libus paludosis (Prowse 240 b).



FIGURE 8

Colourless Eugleninae in Malaya:—

a, *Heteronema invaginatum* Prowse; b, *Heteronema polymorphum* Défl.; c, *Heteronema leptosomum* Skuja; d, *Notosolenus stenochismos* Skuja; e, *Notosolenus orbicularis* Stokes; f-g, *Notosolenus similis* Skuja; h-i, *Notosolenus lens* Skuja; j, *Entosiphon sulcatum* (Duj.) Stein; k, *Entosiphon obliquum* Klebs.

Figure b is at a lower magnification than the others.

Notosolenus Stokes 1884 emend. Skuja 1939

Cells ovoid, elliptical or almost round, distinctly flattened, with a distinct ventral groove which may reach the full length of the cell. Periplast delicate, with or without striations. Cytostome opening curved. Swimming flagellum pointing forward, long, trailing flagellum short. Some forms have a superficial resemblance to *Anisomena* Dujardin emend. Stein, but it is always the long flagellum which points forward for swimming, and not the shorter one. Nutrition saprophytic or holozoic (specimens have been seen in which chloroplast material from *Spirogyra* has been visibly ingested).

Key to the species

1. Cell ovoid, narrowed towards the anterior 2.
1. Cell broadly ellipsoidal, equally rounded at both ends . . . 3.
2. Cell only slightly flattened, narrowing at the anterior end to a more or less blunt point; dorsal surface convex, the ventral surface bearing a shallow lateral groove

(i) *N. similis*.

2. Cell slightly flattened, narrowing at the anterior end, rounded or conical at the posterior end, dorsal face convex, ventral face concave with a deep median groove

(ii) *N. stenochismos*.

3. Cell small, markedly flattened, with a prominent wide, median groove (iii) *N. orbicularis*.

3. Cell much less flattened, lens-shaped, almost round in outline, groove very short (iv) *N. lens*.

(i) **Notosolenus similis** Skuja (Figs. 8f, g).

Cell ovoid, slightly flattened, narrowed towards the anterior end to form a blunt point, broadly rounded at the posterior end; 24–28 μ long $\times$ 15 μ wide. Dorsal face convex, ventral face slightly concave, with a very shallow furrow to one side caused by a slight inrolling of the periplast. Longer swimming flagellum pointing forwards, 1½ body length, shorter trailing flagellum about ½ body length. Cytoplasm clear, with scattered granules of paramylum.

Collected from padi swamps, Malacca.

Reported from Lithuania.

The Malayan specimens are twice the size of the Lithuanian specimens, and the paramylum granules are appreciably larger

than as described by Skuja. Nevertheless they come very close to this species, and it seems better to include them here, rather than erect a new species.

(ii) **Notosolenus stenochismos** Skuja (Fig. 8d).

Cell ovoid, slightly flattened, narrowed and slightly drawn out at the anterior end, notched at one side, rounded to slightly conical at the posterior end; 27μ long $\times$ 14μ wide. Dorsal face very convex, ventral face much less convex with a deep narrow groove, circular in cross-section, and running the full length of the cell, slightly inclined to one side. Swimming flagellum about body length, trailing flagellum about $1/3$ body length. Cytoplasm hyaline, with paramylum granules of varying size, from very small to quite large. Reservoir distinct, showing the two rod-shaped siphon bodies.

Collected from the padi swamps, Malacca.

Reported from Lithuania.

(iii) **Notosolenus orbicularis** Stokes (Fig. 8e).

Cell small, almost circular in outline, broadly rounded at both ends, distinctly flattened, 14μ long $\times$ 12μ wide, slightly convex on the dorsal face, flattened on the ventral face, with a wide median groove running the full length of the cell. Swimming flagellum about body length, trailing flagellum about $\frac{1}{2}$ body length. Cytoplasm faintly granular, with scattered paramylum grains.

Collected from padi swamps, Malacca.

Reported from U.S.A.

(iv) **Notosolenus lens** Skuja (Figs. 8h, i).

Cell small, round ellipsoidal to almost circular in outline, less flattened than the preceding species; $18-20\mu$ long $\times$ 16μ wide, flattened on the ventral face, convex on the dorsal face; ventral furrow very short to almost absent. Swimming flagellum $1-1\frac{1}{2}$ body length, trailing flagellum $1/2-1/3$ body length. Periplast apparently smooth. Cytoplasm clear, to faintly granular, with scattered paramylum grains.

Collected from padi swamps, Malacca.

Reported from Sweden.

Entosiphon Stein 1876

Cells ovoid or ellipsoidal, more or less flattened. Periplast firm, with longitudinal striae, ribs or furrows. Flagella 2, the swimming flagellum being shorter than the trailing flagellum. Possessing a distinctly tubular siphon, which can be extruded at the anterior end.

Key to the species

1. Cell oval, periplast with 4–8 longitudinal ridges

(i) *E. sulcatum*.

1. Cell ovoid, often terminating in a blunt point posteriorly, periplast very delicately striated, longitudinally. Siphon frequently protruded (ii) *E. obliquum*.

(i) **Entosiphon sulcatum** (Duj.) Stein (Fig. 8j).

Cell oval, rounded at both ends, 20μ long $\times$ 14μ wide. Periplast with 4–8 longitudinal ridges. Swimming flagellum less than body length, trailing flagellum up to twice body length. Siphon reaching nearly the full length of the cell. Cytoplasm clear, with scattered small granules of paramylum. Saprophytic or holozoic, often containing ingested particles of chloroplasts.

Collected from fish-ponds, Malacca.

Reported from Europe and America

(ii) **Entosiphon obliquum** Klebs (Fig. 8k).

Cell (in swimming state) ovoid, somewhat truncate at the anterior end, narrowly rounded at the posterior end, usually with a blunt point; 24μ long $\times$ 18μ wide. More frequently the cell behaves metabolically, protruding the siphon (see fig. 8k) and the characteristic shape of the swimming state is obscured. Swimming flagellum about $\frac{1}{2}$ body length, trailing flagellum body length or over. Periplast so very faintly striate longitudinally, that the striations are often not visible. Cytoplasm clear, but the cell is usually packed with oval paramylum granules. Siphon reaching the full length of the cell.

Collected from padi swamps, Malacca. Widespread in distribution.

The Malayan specimens are larger, and the frequent metabolic state obscures any marked narrowing of the posterior end. Nevertheless, this is a very common species, which must inevitably show some variation in behaviour. The extremely fine striations of the periplast make it certain that the Malayan specimens belong here.

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